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MORTALITY STUDIES ON CUTTHROAT TROUT IN YELLOWSTONE LAKE

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Orville P. Ball and
Oliver B. Cope
Fishery Research Biologists

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UNITED STATES DEPARTMENT OF THE INTERIOR

Stewart L. Udall, *Secretary*

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FISH AND WILDLIFE SERVICE

Clarence F. Pautzke, *Commissioner*

BUREAU OF SPORT FISHERIES AND WILDLIFE

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Published by the U.S. Fish and Wildlife Service • Washington • 1961

Printed at the U.S. Government Printing Office, Washington, D.C.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 45 cents

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ABSTRACT

In a study of the Yellowstone cutthroat trout, *Salmo clarki lewisi*, by the U.S. Fish and Wildlife Service, effects of environment on mortality of eggs, immature fish, spawners, and postspawners were measured for various components of the population in Yellowstone Lake (Wyoming). Five methods for estimating mortality of adults on spawning runs are described, with counting and tagging as the principal procedures. Of the total number of eggs deposited in the gravel, 60 to 75 percent died before hatching, and 99.6 percent had died by the time the fingerlings entered Yellowstone Lake. Among adults on spawning runs, mortality was 48.1 percent. Sex ratios on spawning runs were uneven, averaging 1.47 females to 1 male. Very few trout spawned a second time; of those that did, more spawned after a 2-year interval than after 1 year.

In the Arnica Creek runs, 48.6 percent died in the stream, 40.2 percent died later in the lake of natural causes, 7.6 percent were taken by fishermen, and 3.6 percent were alive 2 years later. The white pelican is a serious predator on cutthroat trout in Yellowstone Lake. From 1949 to 1953, fishermen caught 11.6 percent of the catchable trout available to them. Migrations of adult fish in Yellowstone Lake were traced through tagging.

MORTALITY STUDIES ON CUTTHROAT TROUT IN YELLOWSTONE LAKE

By Orville P. Ball and Oliver B. Cope
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The U.S. Fish and Wildlife Service has been engaged in a full-scale study of the Yellowstone cutthroat trout, *Salmo clarki lewisi*, in Yellowstone Lake (Wyoming) for several years. The lake lies within Yellowstone National Park and has become increasingly prominent among the recreational features of the park, especially since World War II. Large increases in fishing pressure and noticeable changes in the fishery developed by 1950, and the National Park Service sought advice from the Fish and Wildlife Service regarding reasonable management methods for this fishery resource.

The problem, one of population dynamics, in Yellowstone Lake was to find the numbers of cutthroat trout, and their sizes, that could safely be taken from these waters. The approach to the problem resolved itself into studies of mortalities and survivals, and still continues in this direction. Studies on the various mortalities operating on the population of cutthroat have resulted in an abundance of data on this species in Yellowstone Lake and tributary waters. Since the cutthroat has received relatively little attention in the past by students of trout biology, the present paper brings together mortality information gathered from the Yellowstone study so that the biology of this important sport fish of western North America can be better understood. Emphasis is placed on mortalities of trout eggs in the gravel, of alevins, of fry and fingerlings in streams, and of adults in spawning runs in streams, and on fishing and natural mortality of adults in Yellowstone Lake after their return to the lake from spawning in the streams.

Information pertaining to the fish and fisheries of Yellowstone Lake dates from the survey of David Starr Jordan in 1889 (Jordan, 1891). Several years later a more comprehensive description of the fish species of the Yellowstone area was published (Evermann, 1893). Some delay was experienced before additional literature appeared concerning the fishes of the park, particularly Yellowstone Lake (Kendall, 1915; Smith and Kendall, 1921; Simon, 1953).

A parasitic tapeworm common among the trout of Yellowstone Lake was first described by Leidy (Hayden, 1871). Hayden himself remarked in this report (p. 97) "We are able to discover but one species of fish in the lake (Yellowstone): and that was trout, weighing from two to four pounds each. Most of them are infested with a peculiar intestinal worm which has been described by Dr. Leidy in a subsequent portion of this report, under the name *Dibothrium cordiceps*." Later

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additional material concerning the anatomy and life history of *D. cordiceps* was compiled (Linton, 1891a; Linton, 1891b; Woodbury, 1934; [2] Bangham, 1951). An important study dealing with this tapeworm and its relation to one of its hosts, the white pelican (*Pelecanus erythrorhynchus*), and which included a quantitative evaluation of predation by pelicans on the trout of Yellowstone Lake was completed by Ward (1922 [3]). Several articles have been devoted to the white pelican not only because of its predator-prey relation to the cutthroat trout, but also because of the very important aesthetic niche the bird fills in the park (Grinnell, 1876; Skinner, 1925; Thompson, 1932).

Within recent years several papers on changes in the fishery at Yellowstone Lake have been published (Moore, Cope, and Beckwith, 1952; Cope, 1957). The biology of the cutthroat of Yellowstone Lake has been studied by Brown and Bailey (1952), Laakso (1955, 1956), Laakso and Cope (1956), Cope (1953a, 1953b, 1956, 1957a, 1957b), and Ball (1955).

The authors are grateful to the National Park Service for cooperation throughout this study. The Yellowstone Park Company extended the assistance of its Boat Division in the compilation of creel-census data and reporting tagged fish caught. The late William A. Dunn, Superintendent, U.S. Fishery Station at Yellowstone Lake, gave considerable assistance to our staff. Many field biologists should be thanked for their contributions to the tagging program. Several research biologists including Martin Laakso, R. A. Fredin, Theodore Widrig, W. F. Carbine, Ross V. Bulkley, and Drs. Ralph Hile James W. Moffett, and Norman G. Benson, have critically read the manuscript.

[2] Woodbury, L. A., Parasites and diseases of the trout of Yellowstone Lake (*Salmo lewisi*), Master of Science thesis, University of Utah, 1934, 60 pages.

[3] Ward, H. B., The pelicans of Yellowstone Lake. Manuscript prepared for U.S. Bureau of Fisheries in cooperation with the U.S. National Park Service, 1922, 20 pages.

BACKGROUND MATERIAL

Yellowstone Lake and tributaries

Weather conditions in the Yellowstone Lake area range from severe winters with abundant snowfall and subzero temperatures to mild, pleasant summers. Winter usually begins in September or October and extends through May. Snow cover on the level may reach a depth of more than 6 feet. The lake usually freezes over in the fall and remains ice-covered until the last of May or early June. These rigorous physical conditions influence the seasonal productivity of the lake and the biology of the fish.

Yellowstone Lake, elevation 7,500 feet, has a surface area of about 90,000 acres and a shoreline of nearly 100 miles (fig. 1). Maximum recorded depth is 325 feet. The lake has 14 major and 26 minor tributary streams.

The principal tributaries used for spawning are Pelican, Clear, and Cub Creeks in the northern section, Columbine and Beaverdam Creeks and the upper Yellowstone River in the Southeast Arm, Chipmunk and Grouse Creeks in the South Arm, and Arnica and Solution Creeks in West Thumb. The lower Yellowstone River drains from the north end of the lake. Fifteen miles below the outlet of the lake is a waterfall which is a fish barrier.

The stream studies in this paper are based on five streams, which are briefly described here.

Arnica Creek drains approximately 20 square miles and is 5.8 miles long.[4] It is the smallest tributary on which extensive tagging took place. The water flow at the trap during the summer, while normally 5 to 7 cubic feet per second, has surpassed 20 c.f.s. during spring floods. Warm springs are largely the cause of moderately high stream temperatures.

Pelican Creek, with almost 100 miles of stream, is the largest tributary at which

[4] Welsh, James P. A population study of Yellowstone blackspotted trout (*Salmo clarkii lewisi* Girard). Ph. D. dissertation, Stanford University, 1952. 180 pp.

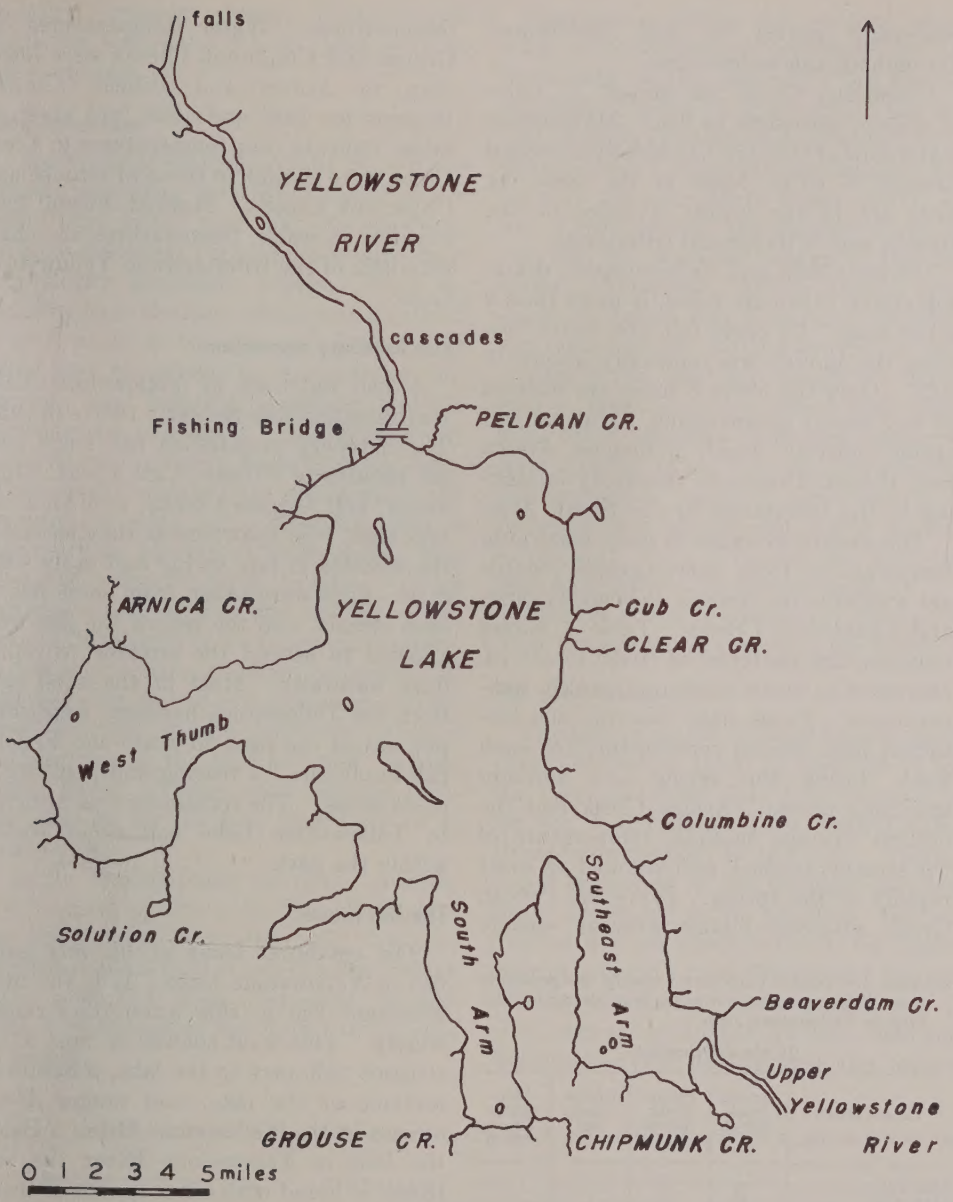

FIGURE 1.—Yellowstone Lake and Yellowstone River, with principal tributaries.

tagging occurred. The drainage area is about 60 square miles. The water flow was measured at 37 c.f.s. during low water in the fall of 1953, but has exceeded 1,000 c.f.s. during June in some years. Numerous warm springs and several geyser basins in this watershed generally restrict spawning to areas least under the influence of warm mineralized water.

Clear Creek on the east shore of Yellowstone Lake includes a total of approximately 24 stream miles. The water flow at the trap was 20 c.f.s. in the middle of August, 1953. The stream has few warm springs and aquatic conditions appeared to be most ideal throughout the summer.

Spawning gravel is well distributed throughout the watercourse.

Chipmunk Creek has almost 22 miles of stream accessible to fish. Midsummer water flow at the trap has usually averaged around 26 c.f.s. Most of the spawning beds are in the lowest 9 miles of the stream and in its several tributaries.

Grouse Creek and its tributaries, draining about 12 square miles, is more than 9 miles long. By early fall, the water flow near the mouth was normally about 13 c.f.s. Only the lower 3 miles are utilized to any extent for spawning. Hot mineral spring activity which influences Arnica and Pelican Creeks so markedly is lacking in the tributaries to the South Arm.

The weekly averages of daily maximum temperatures from thermograph records are available for Arnica, Pelican, Grouse, and Chipmunk Creeks. Table 1 shows temperature patterns at trap locations, expressed as mean maximum weekly temperatures. These data describe the historical high stream temperature for each week during the spring and summer spawning period. Arnica Creek had the highest average seasonal temperature of the streams studied, and warmed up most rapidly in the spring. However, Pelican Creek attained higher average weekly temperatures. Water temperatures in Grouse and Chipmunk Creeks were lower than in Arnica and Pelican Creeks. Records for 1953 and 1954 (not given in table) indicate that temperatures in Clear Creek were similar to those of Grouse and Chipmunk Creeks. Marked diurnal fluctuations in water temperatures are characteristic of the tributaries to Yellowstone Lake.

TABLE 1.—*Mean maximum weekly temperatures from thermograph records in four streams tributary to Yellowstone Lake*

[In degrees Fahrenheit]

Time of season	Arnica Creek 1950–53	Pelican Creek 1950–53	Grouse Creek 1951	Chipmunk Creek 1950–51
May 4–10	43	47	----------	----------
May 11–17	48	43	----------	----------
May 18–24	49	45	----------	----------
May 25–31	53	50	----------	39
June 1–7	53	49	46	40
June 8–14	57	50	44	46
June 15–21	60	51	50	53
June 22–28	60	52	49	51
June 29–July 5	65	59	54	56
July 6–12	64	63	54	55
July 13–19	67	65	60	62
July 20–26	66	68	61	62
July 27–Aug. 2	65	68	61	61
Aug. 3–9	63	65	58	60
Aug. 10–16	64	67	55	61
Aug. 17–23	65	67	----------	----------
Aug. 24–30	62	64	----------	----------
Aug. 31–Sept. 6	60	63	----------	----------
Sept. 7–13	61	57	----------	----------
Seasonal mean	59.2	57.5	54.0	53.8

Fish hatchery operations

A fish hatchery at Yellowstone Lake was operated from the early 1930's to 1953. The hatchery maintained fish traps near the mouths of Pelican, Cub, Clear, Chipmunk, and Grouse Creeks, and obtained eggs from wild spawners as they ascended the streams in late spring and early summer. Eggs were taken from some fish in each stream, and the rest of the fish were allowed to ascend the streams to reproduce naturally. Most of the eyed eggs from the Yellowstone hatchery were shipped out of the park to State and Federal fish hatcheries for rearing and planting in other areas. The remainder was returned to Yellowstone Lake and other waters within the park.

The fish fauna

The cutthroat trout is the only game fish in Yellowstone Lake. It is the most abundant fish in this water, and ranges widely. This trout spawns in most of the streams tributary to the lake, inhabits all sections of the lake, and ranges downstream in the Yellowstone River. Below the falls in Yellowstone River the cutthroat is found with other species of trout.

The longnose sucker, *Catostomus catostomus* (Forster), is found in Yellowstone Lake and is occasionally taken by anglers in the northeast section of the lake, in shallow water. Spawning runs enter Pelican Creek regularly, and records indicate that other streams are occasionally used by this species.

Two cyprinids, the longnose dace, *Rhinichthys cataractae* (Valenciennes), and the

smallfin redside shiner, *Richardsonius balteatus hydrophlox* (Cope), also occur in this drainage.

Spawning runs

Spawning of cutthroat trout takes place during late spring and early summer, somewhat later in the year than the spawning of most cutthroat populations in surrounding Rocky Mountain waters. After ascending from the lake, adults usually spend 2 or 3 weeks in the stream. During this time they participate in the upstream migration, nest building, spawning, and the downstream migration. Adults that survive spawning move back into the lake. Yolk-sac fry emerge from the gravel in the summer or early fall. Most fry begin a downstream movement immediately and spend their first winter in the lake. Others remain in the streams and first enter the lake as fingerlings in the following summer. A few may continue stream residence still another year, but no evidence suggests that trout mature in the tributary streams rather than in the lake or lower Yellowstone River. These trout become sexually mature for the first time as 3- or 4-year-old fish.

In the present paper the term "yolk-sac fry" is used for immature fish whose yolk-sac has not yet been absorbed; "fry" are immature fish 1 inch or less in length which have absorbed their yolk-sacs; "fingerlings" are immature fish from 1 to 5 inches in length.

Spawners entering the streams where traps are in operation have been counted from 1944 to the present. The average numbers of spawners appearing in the various streams are arranged in table 2 by 2-week periods. Some streams support earlier runs than do others (Cope, 1957), Arnica Creek having the earliest spawning run and the warmest water in the late spring. Moreover, Arnica Creek post-spawners (adult fish that have spawned, survived, and are moving toward or have reentered the lake) are caught by fishermen in great numbers earlier than those from other streams. For each stream, a close relation exists between temperature characteristics (table 1), movements of spawners into the stream (table 2), and subsequent entry of spent fish into the lake sport fishery (appendix table 8).

Table 3 contains sex-ratio information from the spawning runs and the catch.

The sport fishery

The fishing season extends from June 15 (May 30, before 1953) to October 15 for the lake, and from July 1 to October 15 for the Yellowstone River from Fishing Bridge downstream to the falls. Fishing is not permitted in the tributary streams while spawning is in progress, but an overlap in time exists between the beginning of lake and river fishing and the end of the spawning runs (table 2). A creel census conducted by the Fish and Wildlife Service has divided the fishery

TABLE 2.—*Cutthroat trout entering spawning runs, expressed as biweekly percentages of average spawning runs*

Time of season	Arnica Creek 1950–53	Pelican Creek 1949–53	Chipmunk Creek 1949–53	Grouse Creek 1951–53	Clear Creek 1953	All Streams 1949–53
May 4–17	4.5	0.4	0.0	0.0	7.1	1.4
May 18–31	23.3	13.3	.0	.0	7.9	11.3
June 1–14	35.9	20.0	19.5	22.8	7.9	23.4
June 15–28	17.0	30.0	27.4	19.9	3.0	22.6
June 29–July 12	11.7	29.6	33.4	36.8	43.5	27.6
July 13–26	6.2	6.6	15.9	16.4	29.9	12.2
July 27–Aug. 9	1.2	.0	3.8	4.1	.6	1.5
Aug 10–23	.1	.0	.0	.0	.0	.0
Aug. 24–Sept. 6	.1	.0	.0	.0	.0	.0
Sept. 7–13	.0	.0	.0	.0	.0	.0
Average number of fish in spawning run	4,170	15,178	11,249	8,896	11,323	10,163
Average duration of run—days	78	46	57	53	72	60

TABLE 3.—*Ratios of females to males in spawning runs of cutthroat trout from Yellowstone Lake and in the catch*

IN SPAWNING RUNS

Stream	1945	1946	1947	1948	1949	1950	1951	1952	1953	Stream average
Arnica Creek						1.50	1.63	1.76	1.37	1.56
Pelican Creek	2.06	1.27	1.68	1.80	1.62	1.66	1.70	1.00	2.00	1.64
Clear Creek	1.39	1.95	1.19	1.08	1.52	1.36	1.12	1.20	1.89	1.36
Cub Creek	1.24	2.03	1.22	1.30		1.27	1.09	1.17	1.47	1.40
Chipmunk Creek	1.65	1.59	1.32	1.74	1.38	1.50		1.18	1.57	1.48
Grouse Creek	1.45	1.18	1.28	1.05	1.59	1.61		1.36	1.37	1.40
Year average	1.55	1.61	1.34	1.41	1.55	1.52	1.25	1.18	1.73	1.47

IN CATCH

Area of lake	1950	1951	1952	1953	Lake average
Fishing Bridge	0.72	1.20	1.56	1.60	1.29
West Thumb	1.21	1.83	1.58	3.21	1.95
Year average	.99	1.51	1.57	2.24	1.62

into several natural components with respect to type and area of fishing (Moore, Cope, and Beckwith, 1952; Cope, 1957a). This division includes angling from the West Thumb, Lake, and Fishing Bridge guideboats and rental rowboats, landings from the private cruisers and private rowboats, the shoreline and river fishing, and the famous Fishing Bridge fishery. The area covered by the shoreline fishery is largely controlled by the road which parallels the lakeshore from West Thumb to Cub Creek via Fishing Bridge. The section around Fishing Bridge, which spans the river at its outlet from the lake, is fished more heavily than any other location (Cope, 1957a). Tourist accommodations are largely centered in this area. Boat docks at Fishing Bridge, the Lake Hotel, and West Thumb offer rental rowboats and guideboats, and have facilities for the launching of private craft. The inaccessible southern half of the lake receives light fishing pressure from the cruisers and guideboats. West Thumb is moderately fished by shoreline and boat fishermen. The central part of Yellowstone Lake is not heavily fished. The locations of boat docks, access roads, and tourist accommodations are largely the cause of the unequal distribution of fishing.

From 1950 through 1957 the total catch estimate for Yellowstone Lake averaged 284,813 fish per year (table 4). Total harvest for the Yellowstone River averaged 25,964 per year from 1951 to 1957. The seasonal distribution of catches in units of the fishery appear in table 5, and the average contribution of each component of the creel census is summarized in table 6. The Fishing Bridge fishery accounted for less than 3 percent of the total average catch from the lake; private rowboats and the shoreline fishery were the most successful.

TABLE 4.—*Total catch estimates for Yellowstone Lake and River, 1950–57*

[In number of fish]

Year	Lake	River	Total
1950	200,015	(1)	(1)
1951	208,255	19,729	227,984
1952	245,277	20,603	265,880
1953	195,873	27,932	223,805
1954	215,933	35,912	251,845
1955	286,056	63,701	349,757
1956	290,221	21,907	312,128
1957	301,155	41,961	343,116

[1] No river census taken in 1950.

TABLE 5.—*Catches in various fisheries for certain years during tagging operations, expressed as percentages of average catch for each fishery*

Dates	West Thumb guideboats and rowboats 1950–53	Shoreline 1951–53	Fishing Bridge-Lake Dock guideboats and rowboats 1950–53	Fishing Bridge 1951–53	Yellowstone River 1951–53
June 1–14	4.4	10.6	3.0		
June 15–28	11.0	25.7	9.6		
June 29–July 12	17.7	24.5	22.7	38.9	29.3
July 13–26	20.1	21.4	21.1	34.8	29.0
July 27–Aug 9	19.8	8.3	17.8	14.4	14.0
Aug. 10–23	19.7	7.9	15.2	7.5	13.8
Aug. 24–Sept. 6	7.1	1.2	8.6	3.9	12.4
Sept. 7–13	.2	.4	2.0	.5	1.5
Average catch	25,058	63,919	48,629	6,158	22,755

TABLE 6.—*Average annual contribution of each component of the Yellowstone Lake fishery as determined by creel census from 1950 to 1955*

Fishery	Percentage of average lake catch
Rental row boats:	
Fishing Bridge–Lake Dock	11.4
West Thumb	9.2
Guideboats:	
Fishing Bridge–Lake Dock	11.5
West Thumb	2.6
Private boats:	
Rowboats	27.8
Cruisers	4.5
Shoreline	30.1
Fishing Bridge	2.9

METHODS

Nest and fry mortality

A study designed to estimate mortality of cutthroat trout eggs in the nest, and the average number of fry produced per nest, was made at Arnica Creek from 1951 through 1953. Mortality with respect to time through the end of the incubation period (terminal mortality) was measured. Observation of spawning activities of adults permitted the indentification of individual nests. A total of 58 redds was marked and carefully excavated at periods of time varying from 4 to 32 days following deposition. The eggs were collected in a wire screen at a point immediately downstream from the nest. The total number of dead and viable eggs in each nest was determined by count. Live eggs that had been damaged and killed as the result of digging could readily be identified when compared with normally deceased ova.

At the onset of hatching in Arnica Creek, fine-mesh screens were installed in the traps and on the racks to lead the downstream-migrating fry and fingerlings into the trap. These small fish were counted, measured, and released downstream. The trap was removed in late September, when a visual stream survey was made upstream to estimate the total number of fish of each size group remaining in the stream. The sum of the seasonal trap count and of those estimated to be remaining in the stream gave a measure of survival through the summer. The numerical difference between the calculated hatch of yolk-sac fry and the estimate of fish of the year alive in September has been termed "fry mortality", and covers the time from hatching (June–July) to the end of the summer (September-October). The egg potential was obtained by multiplying the number of females entering the stream by the average fecundity figure given by Welsh (1952)[5] and assumes complete deposition. To compensate for the action of predators, scavengers, and other sources of mortality that deprive the spawning run of its full egg potential, the highest nest mortality figure, 75 percent, rather than an average or minimum was used to compute the hatch of yolk-sac fry.

[5] Welsh, J. P., A population study of Yellowstone blackspotted trout (*Salmo clarkii lewisi* Girard). Ph.D. dissertation, Stanford University, 1952, 120 pp.

Tagging of adults

The fish traps in Pelican, Clear, Chipmunk, and Grouse Creeks have been operated for many years to collect eggs for fish-cultural purposes. Beginning in 1949 some spawners were tagged and then released upstream for natural reproduction. This program continued through 1953. A constant proportion for each stream (1 in 3, 1 in 7, etc.) was tagged, depending mainly upon the anticipated number in the run. Some tags were applied to adult fish at Pelican and Chipmunk Creeks in 1950 after the spawn had been taken by hatchery men. After tagging, the fish were placed immediately upstream of the trap, a standard technique employed by the Yellowstone hatchery employees.

A new method of estimating stream mortality was introduced in 1953. This procedure involved the tagging of postspawners, as well as prespawners. Because downstream traps were lacking at some wiers, seines and electric shockers were used in some streams to obtain the spent adults.

Arnica Creek (fig. 1) was established in 1950 as an experimental stream for the study of natural spawning. A combination upstream-downstream trap was constructed near the mouth to obtain total counts of upstream and downstream migrants. In the first year, spring floodwaters undercut the apron and rendered the upstream trap only partially effective. Later in the season the lake level rose and inundated the structure, allowing both downstream and upstream escapement. In 1951, all prespawners were caught in the upstream trap, but later the level of the lake rose again, flooded the trap, and allowed some fish to escape downstream.

The Arnica Creek trap was moved farther upstream in 1952 to eliminate further flooding. Again, spring floods and early summer rains interfered to allow a considerable portion of the downstream run to bypass the structure, but the upstream run was enumerated completely, as in 1951. No serious difficulties were experienced in 1953, and complete counts were made of upstream and downstream migrants.

Postspawners were tagged at Arnica Creek in 1953 as a new method of estimating spawning mortality. The total trap counts this year, which gave an absolute measure of spawning mortality, afforded a check on the estimate gained by the upstream-downstream tagging method.

Beaverdam Creek and a few smaller tributaries in the Southeast Arm were included in the tagging operations of 1952. Small portable traps were used at these locations, and only a limited number of prespawners were captured and tagged. Since few fisherman frequent this area, the return of tags from the fishery was negligible. These data are not considered in the present paper.

The fish were obtained at random from the traps and were anesthetized in chloretone (chlorobutanol) or urethane (ethyl carbamate). Although both rendered the trout immobile for tagging, urethane proved to be more desirable (Cope, 1953b). Best results were obtained with a 0.25 to 0.30 percent solution of urethane within a temperature range of 48° to 52° F. At lower temperatures the fish were affected so slowly that they injured themselves by excessive activity in the holding tank. This slow reaction also reduced the rate at which the fish could be handled. At higher temperatures the fish were affected so quickly that under continued exposure some were injured or even killed. Because of this effect and during the latter part of the spawning runs (table 2), tagging was limited to the early part of the morning, when water temperatures were within this favorable range.

Anesthetized fish were tagged, measured and weighed, and scale samples were taken. The tagged trout were then placed in live boxes until complete and normal recovery was indicated. Mortality immediately attributable to tagging and handling was negligible.

When postspawners were later recaptured in the downstream trap or caught during sampling of the spawning population in the stream adjacent to the trap, they were again weighed, their tags were checked and adjusted if necessary, and they were released. This second capture permitted the study of weight loss and length of time spent in the stream during spawning. A number of adults were tagged in Pelican and Chipmunk Creeks in 1950 after having been spawned by fish culturists. These fish were released upstream and some were recaptured through stream sampling. This procedure yielded comparisons between those fish reproducing naturally and those artifically spawned for spawning mortality, weight loss from spawning, and time spent in the stream.

Fish caught in a trap net fished in the lake about 1 mile south of Fishing Bridge were tagged in 1952 and 1953. The tagged trout were released in the area of capture.

From 1951 through 1953, adult cutthroat were tagged at the Cascades of the Yellowstone River, approximately 5 miles downstream from Fishing Bridge. The fish were obtained from a pool in the Cascades where they congregated while moving upstream. Capture was made by hand dip nets and electric shockers, and the fish were treated in the standard fashion before being released. Most of those taken proved to be prespawners.

The Petersen disk was the tag used exclusively throughout this study. Except for the tags used in 1949, an identification was carried on one of each pair of disks (inked, or stamped, or printed numerals). The color of the returned tag established the place of tagging, while the mark on the tag identified the individual fish.

Tags were recovered from several sources. A few were taken from dead fish in streams. Most of the tags were recovered on a semivoluntary basis from fishermen. Posters were placed at strategic points around Yellowstone Lake to inform the public of the presence of tagged fish and the need for their return by the fishermen. The cooperation of boat-dock employees and fishing guides of the Yellowstone Park Company and of National Park Service employees greatly facilitated the return of tags. Many tags were also recovered annually from nests at the white-pelican rookery at Molly Island in the Southeast Arm (fig. 1). The pelican is the principal predator on the cutthroat in Yellowstone Lake. Upon capturing a marked fish, the bird may return to the rookery and regurgitate the fish to feed the young pelicans, or may deposit the tag on the island in fecal material. Tags were recovered by searching in and around the nests.

Visitors to Yellowstone Park were interviewed in 1953 to determine the efficiency of the semivoluntary tag-return system. Road blocks were operated once a week throughout the fishing season at strategic locations near fishing areas. Automobiles were temporarily detained and all tourists were questioned about their fishing at Yellowstone Lake. A total of 26,031 people were questioned between June 21 and September 6.

Tag return areas

Migration of postspawners from the tributaries was measured from the distribution of tag returns from the sport fishery. The lake and river were divided into areas delimited by geographical or fishery characteristics, or both. These areas are indicated in figure 2, with pertinent geographical localities that are concerned with the tag return results.

The Fishing Bridge area is at the outlet of the lake. This area includes Fishing Bridge itself and extends about half a mile upstream and a mile downstream from this structure. The Yellowstone River area extends from the lowermost limit of the Fishing Bridge area downstream to the upper falls, a distance of about 14 miles. The section of Yellowstone Lake lying

FIGURE 2.—Yellowstone Lake and River fishing areas and important geographical locations.

north of a line from Rock Point on the west shore to Elk Point on the east is termed the northern area. The part of the lake to the west of a north-south line connecting Rock Point and Wolf Point is designated the West Thumb area. The rest of the lake is included in the southern area, which incorporates the central part of the lake and Flat Mountain, South, and Southeast Arms.

Stream mortality of adults

Five methods of determining spawning mortality were considered in these studies:

1. Complete upstream and downstream trap counts (Arnica Creek, 1953).

2. Upstream and downstream tagging (Arnica Creek, 1953; Chipmunk Creek, 1952–53; Grouse Creek, 1952–53).

3. Sampling ratio, the downstream sampling of spawners that were tagged on

their way upstream (Arnica Creek, 1950–52; Pelican Creek, 1950; Grouse Creek, 1951).

4. Assumed fishing mortality (Pelican Creek, 1949; Chipmunk Creek, 1949).

5. Complete count of dead fish in the stream.

The complexity and variety of the sampling procedures necessitated the use of these several methods to produce comparable results. The following notations and definitions have been used in the analysis:

T	Tags applied to prespawners.
t	Tags applied to postspawners.
Nu	total adults migrating upstream (prespawners).
Nd	total adults migrating downstream (postspawners).
NT	total number of prespawners tagged NT/week=tag group.
Nt	total number of postspawners tagged Nt/week=time group.
$n(Td)$	sample of NT checked downstream through trap as postspawners $n(Td)$/week=time group.
$N(Td)$	total number of NT checked downstream through trap as postspawners (full availability to the fishery) per week=time group.
(Tf);(tf)	tags returned from the fishery.
sm	number of deaths in stream (stream mortality).
fmi'	instantaneous fishing mortality (a rate).
fma'	seasonal fishing mortality (a rate).
sm'	stream or spawning mortality (a rate).
lm'	natural mortality in lake (a rate).
s'	survival (a rate).
SR	sampling ratio (a factor).

The first method depends upon total upstream and downstream counts of spawning run fish. Tagging is not involved. Therefore, the equation is as follows:

$$sm=Nu-Nd$$

The second method is an estimate. Here, the downstream migration is composed of some fish that were tagged during upstream movement and others that were not. Untagged fish moving downstream are sampled and tagged (t) and released downstream to enter the fishery in numbers approximately equal to the lakeward migration of tagged prespawners, $n(Td)$, in each sample. The method assumes subsequent equal availability in the lake of both $N(Td)$ and Nt, the known quantity. Further, we assume total availability of Nt to the fishery without significant delayed mortality due to tagging or spawning. Therefore:

$$\frac{N(Td)}{(Tf)}=\frac{Nt}{(tf)}$$

Solving for $N(Td)$

$$N(Td)=\frac{Nt(Tf)}{tf}$$

$$sm=NT-N(Td)$$

Evidence of a small mortality due to tagging, to be discussed later, tends to violate one of the assumptions upon which this method is based, and therefore limits its value to some extent.

The third method uses a factor termed the "sampling ratio," SR. As in the upstream-downstream tagging method of estimating stream mortality, random sampling of the downstream migrants containing T is involved. Subsequently, the tags returned from the fishery are used to compute the total downstream migration and the spawning mortality in the following manner:

$$SR=\frac{(Tf)\ (\text{not present in } n(Td))}{(Tf)\ (\text{present in } n(Td))}$$

then

$SR\times n(Td)$ (sampled) $=n(Td)$ (not sampled, escaped downstream); therefore,

$$n(Td)\ (\text{sampled})\ +n(Td)\ \text{not sampled})\ =N(Td)$$

and

$$sm=NT-N(Td)$$

Before the use of upstream-downstream tagging, the sampling ratio was the principal method of estimating spawning mortality at all locations. Sampling took place below the upstream traps to ensure the taking of fish that had completed spawning. Visual inspection of fish obtained aided in this determination. Hence, the sampling ratio establishes a relationship between the number of fish that escaped sampling and those that were sampled. Obviously, the downstream collections must include a large enough number of tagged fish, T, so that the fishery tag returns will provide a reliable ratio of sampled and nonsampled tags. At Arnica Creek (1950–53) the downstream trap which operated inefficiently provided a large enough weekly sample to allow the SR to be applied to the $n(Td)$ for each time period. Following this procedure, if the SR computed from week to week varied significantly within the season, it was applied where appropriate. The $N(Td)$ for the season would then be equal to the summation of estimates for each time period. However, where the variation of the sampling ratio was small, as was the case in 1950 and 1951, the mean SR for the season was applied to each period's $n(Td)$. Postspawners at Arnica Creek apparently avoided the downstream trap at a constant rate in 1950 and 1951 due to early flooding by spring runoff and, later, by the rising of the lake level. In 1952, hampered only by the excessive spring runoff, the sampling rate varied. The small number of tags sampled at other streams restricted the application of the SR to only the total number of $n(Td)$ obtained for the entire season. If enough tags are obtained in the downstream sampling process, then both methods 2 and 3 may be simultaneously employed.

Because identification symbols were lacking on the tags used at Pelican and Chipmunk Creeks in 1949, a fourth method of estimating stream mortality was employed. The more reliable data from later years' tagging for any single tributary indicate that fishing mortality for postspawners varies less from year to year than does stream mortality. Assume, then, that the fishing mortality for each stream, as indicated by the return of tags from the fishery, is similar to an average estimate obtained from the more accurate data of other years. In order to approximate the number of tagged fish that survived spawning, the following relationship must be established where $(fm)a$ is an average estimate derived from data of other years:

$$\frac{(fm)a}{100}=\frac{(Tf)}{N(Td)}$$

solving for $N(Td)$

$$N(Td)=\frac{Tf\times 100}{(fm)a}$$

then

$$sm=NT-N(Td)$$

If all of the adults that died during stream residence could be observed by patrolling the spawning grounds, the tabulation would give total stream mortality. This method has been used in some Pacific salmon studies. However, at Yellowstone, because of the sizes of the tributaries, the rapid destruction of carcasses by scavengers, and the activities of predators, this approach did not give accurate results and was not used.

Mortality in the lake

The determination of mortality in Yellowstone Lake primarily concerned the postspawners returned to the lake from tributaries. Stream mortality estimates made these determinations possible. One method for mortality determination was used for trout from these five streams. Other methods were necessary for fish tagged at the Cascades of the Yellowstone River and at the trap-net site on Yellowstone Lake. At these locations samples were tagged without knowledge of the numerical relation to the population they represented. Furthermore, fish tagged at the

Cascades and at the trap net were immediately available to the fishery, if fishing was in progress at the time of tagging. These factors required modification of the method used for mortality estimates for trout from the tributary streams.

Much of the basis for the methods and definitions in this report is founded on the work of Graham (1938). In dealing with fishing mortality, he defined rate of fishing as the "catch in a moment of time expressed as a percentage of the stock at that moment." This involves the concept of instantaneity. The concept of fishing intensity was presented in terms of the summation effect of fishing season upon a stock of fish.

The methods developed in this report deviate in detail, but not in principle, from Graham's treatment. The influence of the fishery upon the stock of available tagged fish is here termed the intensity of fishing. This may be considered from two viewpoints, the instantaneous (rate of fishing, $(fm)i$) and seasonal (fishing mortality, $(fm)a$) rates.

The rate of fishing is measured in relation to the accumulation of tags available to the fishery (cumulative availability) during a weekly period (time period). The fishery tag returns during that period are expressed as a percentage of the cumulative number available. While Graham dealt with the average number of marked fish available during a unit of time, we used, instead, the total number of available fish accumulated to the end of the unit of time. This was considered to be most desirable, since tagging and escapement to the fishery occurred before and during the most intense fishing period. Also, instead of treating instantaneous mortality in terms of number of tags liberated per instant of time and simultaneous relation to returns, as has been suggested by Ricker (1948), the analysis was based on the accumulation of tags throughout the summer season, notwithstanding limitations imposed by concurrent, natural mortality. This method is considered to provide a more accurate measure of the effects of fishing where numbers of returns were small. The rate of fishing, therefore, may best be defined as the number of tagged fish captured by fishermen within an instant of time (weekly period) divided by the accumulated available tag population tabulated to the end of that instant of time.

The rate of fishing may also be expressed as an instantaneous fishing mortality per 100 fish available within a period of a week. This value can be assumed to approach the rate of exploitation affecting the total available fishable population within the scope of tag dispersion. The concurrent effect of natural mortality (the rate of which has not been determined) cannot be isolated in this treatment; therefore, the resulting errors cannot be eliminated.

Rate of fishing is also presented in a slightly different light, and is termed "period fishing returns" or "rate of tag return." This method, involving a slightly different concept of time, is intended to render the less complete data comparable with information from all tagging locations and with the creel census catch statistics. The period fishing returns relate the number of tags identified with a particular stream or area returned within a time period to the season's total for that population. The statistic is expressed as a percentage of the total for the season.

Seasonal fishing mortality $(fm)a$ is treated by two methods. The first method deals with the survivors of an upstream group tagged during a time period and with the subsequent returns from the fishery. This requires precise data involving tag group stream mortality rates for each time period and has been used only at Arnica Creek. The measure is called "tag group fishing mortality." It represents the relation between the survivors of an upstream tag group processed within a time period and the subsequent returns for a fishing season. Stream mortality and biology are intervening variables

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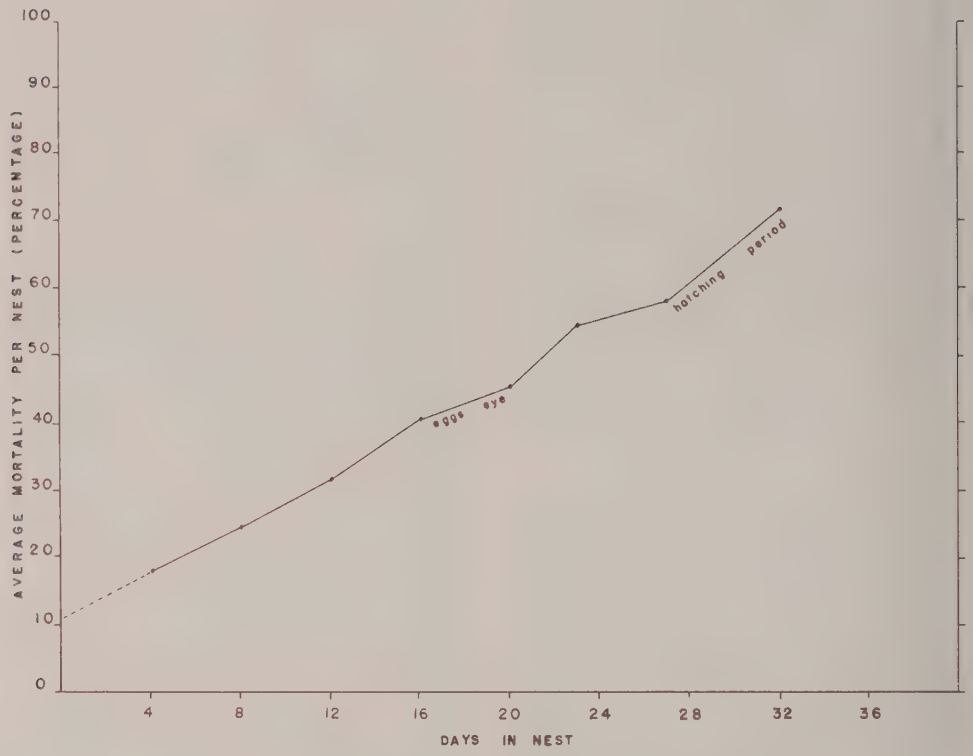

FIGURE 3.—Mortality to eggs from deposition to hatching.

that determine group availability and catch.

The other method is termed "time group fishing mortality." The approach is concerned with tags actually checked downstream to the fishery during any given time period, a time group, and the subsequent fishery returns during the season. Stream mortality and biology have been eliminated as variables because this tag unit originates during each week as a portion of the downstream migration. It was either totally enumerated (Arnica, 1953) or adequately sampled (Arnica, 1950–52). At other stream locations where downstream sampling was inadequate, this method was not applicable. At the trap net and Cascades, the tag and time group are synonymous, since the fish were immediately available to the fishery at the trap net and were practically so at the Cascades. When considered on a seasonal summary basis, both methods of evaluating fishing mortality of tag groups or time groups are identical; the principal difference between these two methods lies in the identification of the tag units.

RESULTS

Egg, fry, and fingerling mortalities

The results of the egg mortality measurements at Arnica Creek (1950–53) are summarized in table 7. A total of 58 nests was examined, almost equally divided between 1952 and 1953. Only six nests were included in 1951. The sampling of nests with respect to time was accomplished in proportion to the intensity of spawning, as much as possible. Since there were no discernible differences between the results of 1952 and those of 1953, all data

TABLE 7.—*Summary of egg mortality data, Arnica Creek, 1951–53*

Days in nest	Development events	Average number of eggs and fry	Number of nests sampled	Number of eggs		Percent dead	
				Alive	Dead	Mean	Range
4		423	7	349	74	17.5	1.3–30.8
8		283	8	215	58	24.0	5.0–45.7
12		349	8	238	111	31.5	6.6–40.1
16	Eggs become eyed	354	8	211	143	40.4	6.9–100
20		422	10	231	191	45.3	9.9–62.2
22-24		410	10	152	225	54.9	11.0–100
26-28	Hatching starts	319	7	135	184	57.7	4.5–100
32		229	3	57	172	75.1	63.0–100
36-40	Hatching completed	56	3	3	161		
Season		369	58				

TABLE 8.—*Summary of fry mortality data, Arnica Creek, by years, 1950–53*

	1950	1951	1952	1953	Average
Egg potential	2,578,203	3,263,436	2,485,215	2,904,768	2,807,905
Yolk-sac fry (25 percent of egg potential)	644,551	815,859	621,304	726,192	701,976
Number of fry and fingerlings	27,712	13,488	597	4,384	11,545
Percentage of hatch	4.29	1.65	.09	.60	1.64
Percentage of egg potential	1.07	.40	.002	.15	.40
Mortality to September (percent of egg potential)	98.93	99.60	99.97	99.85	99.60

were combined. Figure 3 depicts the mortality rate of eggs in the nest and is based on the information contained in table 7. The terminal nest mortality ranged from a minimum of 60 to a maximum of 75 percent. To compensate for the action of predators and other mortality sources that deprive the spawning run of its full egg potential, the apparent maximum nest mortality, rather than an average nest mortality, was applied. The results depict the number of yolk-sac fry estimated to have hatched.

Table 8 compares each year's production of yolk-sac fry in Arnica Creek with the estimated number of immature fish surviving in September. The difference between these two quantities is termed fry mortality.

The average nest mortality at the end of the first 4 days was 17.5 percent. Thereafter, the average mortality increased at the rate of about 6 to 7 percent for every 4 days through the 32nd day of incubation. The period of incubation here includes embryological development to hatching, but not into the yolk-sac stage. Based on the presence of yolk-sac fry in the gravel, hatching apparently began during the period from the 28th through the 32d day of incubation. As water temperature increased through the spawning period, time required for incubation decreased.

The results of these studies indicate an average time-mortality relation which approximates a straight-line function. It might be expected that a significant decrease in the mortality rate would be detected around the end of the third week in the nest. At that time the delicate stage of embryonic development is completed and the eggs become eyed. Incubation of cutthroat trout eggs at the Yellowstone hatchery has demonstrated that such a decrease is the rule rather than the exception. A decrease in mortality rate did not occur in the Arnica Creek studies. However, eggs in the hatchery are mechanically jarred (bumped) at the onset of the eyed stage. This operation is intended to induce an immediate mortality of the eggs that otherwise might die during the remainder of the incubation period. Hatchery-water temperatures are relatively constant without daily or seasonal fluctuation, and provide a stable environment throughout the

developmental period. These artificial conditions are not duplicated in nature where the eggs are usually not mechanically disturbed in the nest, and diurnal and seasonal temperature variations occur. These conditions likely contribute to the observed uniform mortality rate of eggs in nature.

Extrapolation of the mortality curve (fig. 3) to the zero time point, which assumes a constant mortality rate from egg deposition, suggests an initial loss of approximately 10 percent. Other salmonid nest studies (Briggs, 1953) have shown fertilization to have efficiencies of 94–98 percent. It is suggested that if an initial loss of 10 percent is the case in the present studies, it may be attributable to both mechanical injury of eggs during spawning and lack of complete egg fertilization. Other sources of egg mortality that may operate to various degrees throughout incubation include high water temperature, disease, redd exposure due to lowering of water level, exposure due to superimposition, invertebrate predation, and silting of the redds.

The total number of eggs (dead and alive) uncovered from the 58 nests involved in this study amounted to 21,398. Disregarding deterioration of dead eggs (Briggs, 1953), the average number of eggs per redd was 369, with a range of from 229 to 423. The average fecundity of the Arnica Creek spawners in 1950 and 1951 was 1,107 eggs per female, with the smaller females (290 mm. or less in length) harboring 898 eggs and the largest size group having 1,296 eggs per female (Welsh, 1952). Using these independent averages, the results indicate that each female must prepare three nests in order that all of her eggs be deposited.

After hatching, the ensuing mortality measurement extends from the yolk-sac stage through the fry and fingerling stages in the fall of the year. From 1950 through 1953, an estimated average of 701,976 yolk-sac fry were produced yearly in Arnica Creek (table 8). Subsequent survival of fry and fingerlings to September varied from less than 1 percent (1952 and 1953) to 4.3 percent (1950). Considerable variation from year to year is evident and should be expected in this production. Of the 4-year total of 46,181 immature fish enumerated in September, 60 percent were accounted for in 1950 alone, and almost 90 percent in 1950 and 1951 combined. As a rule, 1.6 percent of the yolk fry production, or 0.41 percent of the egg potential, survived through the critical summer period. This amounts to an average fry sac mortality estimate of 98.4 percent (95.7 to 99.9 percent). There was no apparent relation between numbers of females involved in natural reproduction at Arnica Creek from 1950 to 1953 and the resulting production of fry. Similar negative relations have been detected in several salmon populations (Barnaby, 1944; Foerster, 1945).

Other studies of salmonid survival have also noted considerable variation between individual nests both within a single sampling area and from year to year. Survival for the Lahonton cutthroat trout (*Salmo clarki henshawi*) from the egg to the fry stage (3 months after emergence from the gravel) was shown to be 16 to 17 percent in 1 year. In the 2 years that followed, survival varied from 0 to 6 percent (Smith, 1947). Small numbers of nests and fry were used in these tests. In the same study, the survival of brook trout (*Salvelinus fontinalis*), measured from egg deposition in November to the following August, ranged from 3.6 to 42.4 percent and averaged 16.4 percent for 6 sampling units. Briggs (1953), with methods similar to those used at Arnica Creek, found an average terminal nest mortality of 35.1 percent for steelhead trout eggs, with great variations between samples. Comparable mortality figures for king salmon (*Oncorhynchus tschawytscha*) and silver salmon (*O. kisutch*) of 14.0 and 25.7 percent, respectively, were also listed. A tabulation of nest mortalities from various studies cited in the reports of Briggs, (1953)

TABLE 9.—*Summary of salmonid nest mortality data from Briggs (1953), Shapovalov and Taft (1954), and the present study*

Species	Authority	Number of redds sampled	Terminal mortality
Data from Briggs:			*Percent*
Red salmon	Chamberlain (1907)	58	("two-thirds in good condition").
Brook trout	White (1930)	1	21.0.
Do	Hazzard (1932)	[1] 21	19.2.
Red salmon	Foerster (1938)		30.0.
Coastal cutthroat	Cramer (1940)	[1] 4	95.2.
Atlantic salmon	White (1942)	1	22.0.
Chum salmon	Hunter (1948)	[2] 10	86.3.
Pink salmon	Hunter (1948)		96.8.
Brown and rainbow trout and king salmon	Hobbs (1948)	711	8.6.
Data from Shapovalov and Taft:			
Silver salmon	Harrison (1923)		25.0.
Do	Carl (1940)		46.3.
Do	Shapovalov and Berrian (1940)		89.8 (heavy silting).
Do	Shaw and Maga (1943)		83.8 (some silting).
			98.8 (artificially introduced mining silt).
Do	Foerster (1944)		88.6.
			88.2.
			69.6.
			74.0.
			74.4.
			60.0.
			59.9.
			83.7.
Steelhead trout	Shapovalov (1937)		71.2. (silting).
			20.1 (no silting).
Arnica creek data:			
Cutthroat trout	Present paper	58	60–75.

[1] Prehatching.
[2] Distributed between chum and pink salmon.

and Shapovalov and Taft (1954) provides data comparable with those from Arnica Creek (table 9).

Terminal nest mortality at Arnica Creek, 60 to 75 percent, appears to be similar to the average of those indicated from most other salmonid studies. However, two factors should be considered and weighed in order to make nest and fry mortalities significant, comparable, and objective. These items are the fecundity of the species and mortalities through the various developmental stages, particularly during the most critical segments of the life history. For instance, at Yellowstone Lake, in order to maintain numerical equilibrium in the spawning runs over a period of time, each mature female is responsible for the ultimate production of 1.67 adults, because of the unequal sex ratio in the spawning runs. To meet this requirement, a 0.15 percent survival from the 1,107 eggs per average female is necessary. Survival as high as 0.41 percent from egg potential to the stages in September has been measured at Arnica Creek. That is, 4.54 young trout per female had been produced to this point. Only 1.67 of these are required to reach maturity if the run is to remain in numerical stability. Thus, over a period of 3 years, which covers normal elapsed time to sexual maturity, 3.33 (63.20 percent) of the 5 immature fish alive in September will succumb. The survival rate of 36.80 percent suggests very favorable environment for the preadult period in the lake.

Many factors may influence the success of natural reproduction of cutthroat trout and survival during early developmental stages at Yellowstone Lake. They are:

1. Size of the spawning run (egg potential).

2. Capacity of the spawning gravels to accommodate spawners without occurrence of superimposition.

3. Predator population levels.

4. Relation between the advent of unfavorable environmental conditions in the stream and the onset, peak, and completion of spawning. The survival of adults, eggs, and fry is sometimes determined to a great extent by this relation (for example, lethal stream temperatures,

redd exposure due to lowering of stream level, silting and scouring of spawning gravels).

5. Log jams and other barriers of a temporary or permanent nature that render upstream spawning areas inaccessible and may result in superimposition in overcrowded downstream reaches.

6. Ability of the nursery areas to produce a sufficient supply of usable food for the newly hatched fry. The availability of food for young fish is especially critical at and shortly after the time when the yolk becomes absorbed.

7. Intrusion of temporary barriers (low water, hot springs) that might prevent free and uninhibited movement of fry from the spawning gravels to suitable nursery areas.

Stream biology and spawning mortality

The mortality to spawners during their sojourn in the spawning stream has been the subject of considerable attention during these studies. It is at this time of the life history that cutthroat trout are assembled in close quarters on the upstream and downstream migration, and the biologist is afforded the best opportunity for obtaining information on various aspects of its biology. In the section on Methods (p. 7), explanation was made of various procedures in measuring mortality to adults in streams. The results of the applications of these methods and of modifications used for mortality due to tagging are treated in the sections to follow.

Stream mortality of tagged vs. untagged trout.—The stream mortality estimates at Yellowstone have been examined in the light of possible differential mortality due to tagging. The anaesthesia, handling, and tagging were suspected of causing weakness in the tagged fish, spoiling the assumption that tagged fish acted exactly as did untagged fish.

The facilities at Arnica Creek were used to compare the upstream mortalities of groups of tagged and untagged trout from 1950 to 1953. Table 10 summarizes mortality for each group, and shows that tagged fish sustained mortalities of from 35 to 50 percent while in the stream. Untagged trout incurred stream mortalities ranging from 25 to 44 percent. Tagging imparted a maximum of 12 percent additional mortality on the spawners (1951), and a minimum differential of 4 percent (1950). The tagging mortality in Arnica Creek may also have been due to the impediment of wearing the tag during the migration, nest digging, and spawning. Individual differences in tagging and handling techniques among personnel could have contributed to year-to-year variations in mortalities between tagged and untagged fish.

TABLE 10.—*Differential stream mortalities at Arnica Creek, by years, 1950–53*

Cutthroat trout	1950	1951	1952	1953
Tagged vs. untagged:				
Tagged fish mortality (percentage)	38.0	41.2	35.3	50.3
Untagged fish mortality (percentage)	33.6	29.1	25.6	44.2
Differential mortality (percentage)	4.4	12.1	9.7	6.1
Chi square value	[1] 6.198	[2] 62.089	[2] 32.162	[2] 11.644
Male vs. female:				
Male sample mortality (percentage)	18.1	27.0	22.3	60.1
Female sample mortality (percentage)	18.9	26.0	25.3	44.6
Differential mortality (percentage)	.8	1.0	3.0	15.5
Chi square value	[3] .0304	[3] .6370	[3] 1.1117	[2] 11.397

[1] Significant (0.5 level).
[2] Highly significant (0.01 level or better).
[3] Not significant.

Mortalities in streams.—The test stream, Arnica Creek, was used for stream mortality measurements from 1950 to 1953, and afforded a convenient means for comparisons between methods in years when more than one method was used. Table 11 shows, for instance, that in 1953 two methods were used; these will be compared later. The table also shows the methods used for mortality estimates for other spawning populations and for trout in Yellowstone Lake.

Table 12 summarizes the corrected and uncorrected counts of trout through the Arnica Creek trap upstream and downstream, for the years 1950–53. Table 13 is a summary of all stream mortality estimates made from 1949–53.

The most reliable mortality estimates made were those on Arnica Creek. In one year, 1953, there was no escapement past the trap in either direction, so perfect counts were obtained. In years when some trout evaded the trap, corrections were made (table 12) from the results of a marking program.

Stream mortalities reported for other streams (table 12) were computed by the other methods indicated in table 11 and described in the section on methods. These methods are all dependent on the recovery of tags from postspawners in the lake and river fishery. Table 14 is a general summary of tags representative of postspawners from various streams and returned from the fishery. The "assumed fishing mortality" method used on Pelican and Chipmunk Creeks for 1949, giving mortality values of 65.2 and 23.0 percent, respectively, while not yielding statistically reliable results, nevertheless affords the most reasonable approximation possible under the circumstances.

The upstream-downstream tagging method gave reliable estimates in some instances. At Arnica Creek, this method was tested against a complete upstream and downstream trap count in 1953. The stream mortality estimate made by upstream-downstream tagging was 52.2 percent, compared with 50.3 percent for the actual count. In this case, 29 out of 353 downstream tags were recovered in the fishery in the current season. On other streams where the method was used in

TABLE 11.—*Summary of methods used in evaluating stream and fishing mortality*

Area and year	Stream mortality				Fishing intensity			
	Sampling ratio	Upstream-downstream tagging	Complete count	Assumed fishing mortality	Period returns	Tag group	Time group	Rate of fishing
Arnica Creek:								
1950	X				X	X		X
1951	X				X	X		X
1952	X				X	X		X
1953		X	X		X	X	X	X
Pelican Creek:								
1949				X	X			
1950	X				X			
1951	X				X			
1952	X				X			X
1953	X				X			X
Chipmunk Creek:								
1949				X	X			
1950	X				X			
1952		X			X			X
1953		X			X			X
Grouse Creek:								
1951	X				X			
1952					X	X	X	X
1953					X	X	X	X
Cascades:								
1951					X	X	X	X
1952					X	X	X	X
1953					X	X	X	X
Trap net:								
1952					X	X	X	X
1953					X	X	X	X

TABLE 12.—*Corrected and uncorrected trap counts at Arnica Creek, by years, 1950–53*

Tagged fish	1950	1951	1952	1953	Total
Upstream:					
Number tagged	965	1,252	958	1,019	4,194
Number untagged	[1] 2,916	3,503	2,565	3,505	12,489
Total count	3,881	4,755	3,523	4,524	16,683
Sampling ratio (SR)	3.15:1	1.82:1	[2] 0.3–5. 0:1		
Percentage tagged	24.9	26.3	27.2	22.5	25.1
Downstream sampled:					
Tagged fish	144	261	232	506	1,143
Untagged fish	559	1,153	869	1,956	4,537
Total	703	1,414	1,101	2,462	5,680
Downstream estimated:					
Tagged fish	598	736	620	506	2,460
Untagged fish	1,936	2,484	1,908	1,956	8,284
Total	2,534	3,220	2,528	2,462	10,744
Stream mortality:					
Tagged fish	367	516	338	513	1,734
Untagged fish	980	1,019	657	1,549	4,205
Total	1,347	1,535	995	2,062	5,939
Total:					
Upstream run	3,881	4,755	3,523	4,524	16,683
Downstream run	2,534	3,220	2,528	2,462	10,744
Upstream mortality	1,347	1,535	995	2,062	5,939

[1] Estimated from marking of 764 in upstream trap count
[2] Variable between these limits.

TABLE 13.—*Summary of stream-mortality estimates of spawners* (sm), *by years, 1949–53*

[Expressed as percentage values]

Stream	In tag population of—					Mean
	1949	1950	1951	1952	1953	
Arnica Creek	------	38.0	41.2	35.3	50.3	41.2
Pelican Creek	65.2	60.8	29.2	21.0	30.5	41.3
Chipmunk Creek	23.0	65.7	------	94.9	48.0	57.9
Grouse Creek	------	------	44.2	58.9	70.1	57.7
Clear Creek	------	------	------	------	41.2	41.2
Mean	44.1	54.8	38.2	52.5	48.0	48.1

TABLE 14.—*Summary of recoveries from the fishery of fish tagged in streams*

Stream and year of tagging	Percent of total returns in—										Total number of returns	
	Yellowstone River area		Fishing Bridge area		Northern area		Southern area		West Thumb area			
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
Arnica Creek:												
1950	4.5	--------	9.1	7.7	22.7	15.4	4.5	7.7	59.1	69.2	44	13
1951	2.5	--------	8.6	--------	12.3	50.0	--------	16.7	76.5	33.3	81	12
1952	--------	--------	5.7	--------	22.9	50.0	2.9	--------	68.6	50.0	35	2
1953	2.9	--------	--------	6.7	14.5	20.0	7.2	6.7	75.4	66.7	69	15
All years	2.7	--------	5.7	4.8	16.6	28.6	3.5	9.5	71.6	57.1	229	42
Pelican Creek:												
1949	--------	--------	30.8	21.4	46.2	71.4	7.7	--------	15.4	7.1	26	14
1950	5.6	--------	37.0	11.1	57.4	55.6	--------	11.1	--------	22.2	54	9
1951	2.9	--------	11.4	29.2	74.3	62.5	4.3	--------	7.1	8.3	70	24
1952	3.5	--------	27.1	--------	64.7	92.3	3.5	--------	1.2	7.7	85	13
1953	1.0	4.3	19.2	8.7	66.3	52.2	6.7	13.0	6.7	21.7	104	23
All years	2.7	1.2	23.3	15.7	64.6	65.1	4.4	4.8	5.0	13.3	339	83
Clear Creek 1953	--------	--------	11.6	--------	62.8	54.5	11.6	18.2	14.0	27.3	43	11
All years	--------	--------	11.6	--------	62.8	54.5	11.6	18.2	14.0	27.3	43	11
Chipmunk and Grouse Creeks:												
1949	--------	--------	--------	--------	9.1	23.5	27.3	17.6	63.6	58.8	11	34
1950	5.9	--------	--------	--------	23.5	33.3	41.2	41.7	29.4	25.0	17	12
1951	--------	--------	--------	--------	32.1	--------	46.4	73.3	21.4	26.7	28	15
1952	--------	20.0	--------	--------	50.0	20.0	33.3	40.0	16.7	20.0	12	5
1953	--------	--------	--------	--------	19.0	20.0	61.9	60.0	19.0	20.0	21	5
All years	1.1	1.4	--------	--------	27.0	19.7	44.9	38.0	27.0	40.8	89	71

1953, less reliable estimates were obtained because of a paucity of returns from the fishery. From Chipmunk Creek, only 5 out of 112 tags were recovered; from Grouse Creek, 7 out of 172; from Pelican Creek, 2 out of 77; from Clear Creek, 19 out of 595. The reliability of stream mortality estimates by this method depends on a high return of tagged fish from the fishery, and on tagging and release of the downstream migrants at the same time that those not being tagged are passing downstream.

The other technique used at Yellowstone for estimating stream mortality, the sampling ratio method, was employed on four streams. The reliability of this method is also dependent on an adequate harvest of tagged fish. At Pelican Creek in 1953, there were 114 returns from 1,246 fish tagged, giving a more reliable estimate; the figure for Chipmunk Creek in 1951 may be questionable, since only 19 tags from 1,491 tagged fish were returned.

Spawning mortality at stream locations other than Arnica Creek has suggested significantly high death rates. These data lack the reliability of the information derived from Arnica Creek. Because differential mortality estimates pertaining to tagged and untagged spawners are not available from other areas, the spawning mortality values presented in later summaries are derived from tagging data only and are therefore comparable only for the tagged populations. Hence the figures probably represent maximum estimates and could be from 4 to 12 percent high.

Pelican Creek, a moderately warm stream with a large drainage area, supports a relatively early spawning migration. Stream mortality averaged 41.3 percent for the period 1949–53, and great fluctuation about this mean figure occurred. It is noteworthy that the two years of lowest survival of spawners at Pelican Creek were 1949 and 1950, when the two largest spawning runs were tabulated.

Both Grouse and Chipmunk Creeks also averaged more than 50 percent spawner mortality. It is remarkable that the averages computed during the study period for both streams, notwithstanding independent year-to-year variations, were exactly

the same, 56.8 percent. However, the most obvious sources of spawning mortality operating in Arnica and Pelican Creeks, high water temperatures and pollution, are not duplicated in these two tributaries to the South Arm. Predation by white pelicans seems to act as the principal mortality source in this area. The pelican-trout relation will be discussed later.

The tagging operations at the trap net and Cascades depended on spawning migrations passing these two locations. Shortly after tagging, the fish were characteristically taken in the area around Fishing Bridge. Less than 10 percent of the tags applied at the trap net later appeared at the trap on Pelican Creek, which is the spawning tributary nearest the trap net location. Large quantities of excellent spawning gravel are present for a distance of half a mile upstream and a mile downstream from Fishing Bridge. Trout build nests in this area during June and early July, and large numbers of fry are seen there later in the season. Sexually mature fish, many of which are prespawners, dominate the Fishing Bridge fishery. This direct and indirect evidence is the basis for concluding that the fish tagged at the Cascades were moving up the Yellowstone River to spawning gravels around Fishing Bridge. The trap net also sampled mature "lake" fish, most of which were leaving the northern section of the lake for the same spawning area near Fishing Bridge.

The migration of trap-net fish to the Fishing Bridge spawning gravels began during the latter half of June and reached a peak during the last week of the month. Adult "river" trout appeared to be moving up the Yellowstone River earlier in June, at least before the migration of "lake" fish past the trap net location was detected. Maximum movement of river fish took place early in July, indicating a more extended spawning run. Both the opening of the lake fishery (May 30 or June 15) and the onset of fishing in the river and on Fishing Bridge (July 1) exerted a profound influence over the reproductive activities in this particular area.

Adult fish tagged at traps in smaller streams were not available to the fishermen until spawning was completed and the survivors had returned to the lake. On the other hand, fish from the trap net and Cascades tagging operations were exposed to the fishery before, during, and after spawning activities. For this reason the estimate of lake mortality (*lm*) for the last two groups of tagged fish also includes some cumulative effects of spawning mortality.

The Fishing Bridge area fishery has some characteristics that are similar to those detected at Grouse and Chipmunk Creeks. In the South Arm, the white pelicans prey heavily on adult fish in the stream during spawning. Similarly, angling in the Fishing Bridge area depends on adult cutthroat as they approach the spawning gravels, are in the process of nest building, or as postspawners. Observations strongly suggest that in both locations, a significant portion of the harvest by predators and fishermen consists of prespawners.

Stream mortalities and sex.—With one exception, male and female spawners sustained similar spawning mortalities. The reason for a mortality difference between sexes in Arnica Creek in 1953 may relate to temperature. That year, spawning mortality was significantly higher than in previous years (table 10). Mean maximum period temperatures in the stream reached the critical stage, around 65° F., early and were sustained at this level over a longer period of time than in any of the other years at Arnica Creek (fig. 4). This year, the male spawners spent two days more than the average time in the stream (table 15), and an unusually large number of bears frequented the area. These three conditions may have increased the probability of the male population experiencing a significantly higher stream mortality than the female. Presumably these con-

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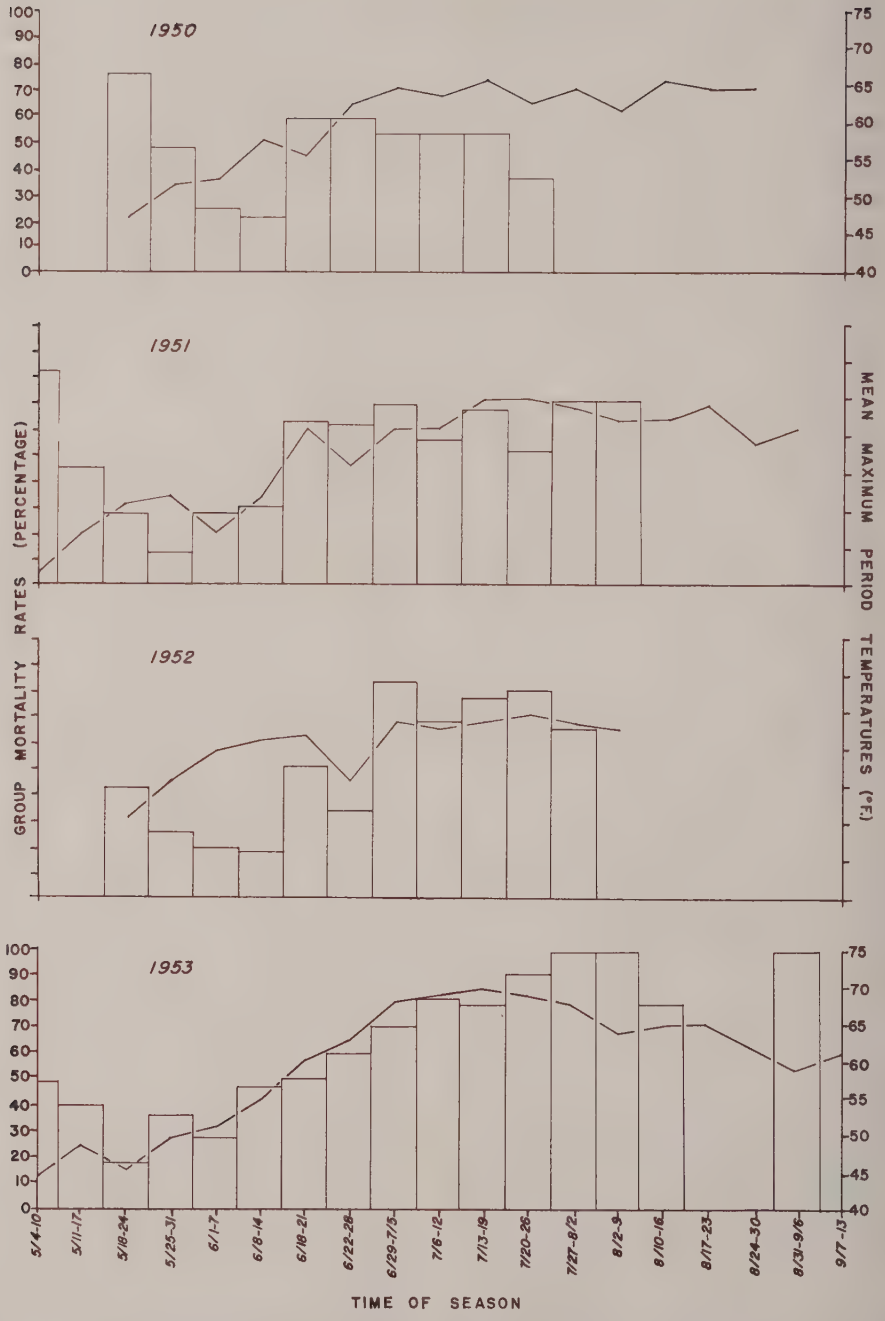

FIGURE 4.—Arnica Creek tag group mortality rates (histograms) and mean maximum period temperatures plotted against time period, 1950 to 1953.

TABLE 15.—*Weight loss and spawning time for tagged trout in Yellowstone streams, 1950 to 1953*

Year, stream, and number of tagged trout	Average loss in weight (ounces)	Average time upstream (days)	Quality of sampling
1950:			
Arnica Creek:			
49 males	3.2	20.3	Good.
73 females	3.9	11.5	
Pelican Creek, artifically spawned:			
5 males	3.2	8.2	Fair.
47 females	2.4	8.9	
Chipmunk Creek, artificially spawned:			
43 males	2.2	9.9	Good.
74 females	2.7	6.3	
Pelican Creek, natural reproduction:			
38 males	3.9	23.3	Fair.
24 females	3.8	21.0	
Chipmunk Creek, natural reproduction:			
48 males	----------	20.2	Good.
59 females	----------	13.1	
1951:			
Arnica Creek:			
92 males	3.2	17.4	Good.
144 females	3.8	10.5	
Pelican Creek:			
1 male	2.5	23.0	Poor.
10 females	2.8	11.4	
Grouse Creek:			
1 male	4.0	31.0	Poor.
1 female	1.0	10.0	
1952:			
Arnica Creek:			
50 males	2.5	12.3	Good.
146 females	2.5	6.0	
1953:			
Arnica Creek:			
159 males	2.4	19.2	Good.
394 females	3.0	12.0	
Pelican Creek:			
4 males	2.4	18.5	Poor.
5 females	2.6	20.2	
Grouse Creek:			
5 males	2.2	18.4	Fair
11 females	2.8	10.2	
Chipmunk Creek:			
2 males	2.5	35.0	Poor.
0 females	----------	----------	
Clear Creek:			
6 males	3.2	17.1	Poor.
22 females	4.4	18.7	

ditions were not critically accentuated in other years to a degree where the effect was differentially applied.

Female spawners in Arnica Creek lost an average of 2.5 ounces in 1952 to 3.9 ounces in 1950 during stream residence, while the male losses ranged from 2.4 ounces in 1953 to 3.2 ounces in 1950 and 1951. The 4-year average showed a 3.3-ounce weight loss for females and a 2.8-ounce loss for males, a difference of almost half an ounce.

Sex ratios.—Sex ratios in the spawning migrations in tributaries to Yellowstone Lake are somewhat unusual in their predominance of females. Table 3 is based on sex determination of 193,305 males and 284,893 females in 6 tributaries at Yellowstone from 1945 to 1953, and on several thousand mature fish caught at random from Yellowstone Lake. The data clearly show that females consistently outnumber males in the migrations and in the catch. The male-female ratio for combined data from the spawning runs is 1:1.47, and for the fishery, 1:1.62.

The phenomenon of a female-dominated sex ratio in the spawning runs at Yellowstone would appear to be important in regard to reproduction potential. There is, however, no evidence that the uneven sex ratio is detrimental to the maintenance of the population of the cutthroat trout.

The reason for the development of the unequal sex ratios in the spawning runs at Yellowstone Lake remains to be explained. It is assumed that the sex ratio of those fry emerging from the gravel is 1:1. Then, at some later time preceding their maturity, either a differential mortality occurs, or the sexes do not enter the streams for spawning in equal numbers. It has been suggested by other workers (Barnaby, 1944) that at the onset of the spawning migration, when the prespawners are approaching the tributary streams and are vulnerable to the fishery, the male may be more susceptible to the fishery. It is well known that male salmonoids are particularly aggressive during the time of reproduction. The thought has been advanced that they may be especially easy to catch at this time. This possibility was explored in an analysis of the sex ratios of the fish during the early portion of the fishery. While a significant predominance of males was noted early in the season, the females outnumbered the males for each season, 1950 to 1953. The total catch involved could not possibly account for the unequal ratio detected later at the traps. If this early fishery was mostly the cause of the differential harvest, then the heavier fishing pressure directed against the northern and West Thumb areas should result in much

stronger spawning-run ratios in favor of the females in these areas, compared with those of the southern half of the lake.

Actually, a suggestion of higher female-to-male ratios in Pelican and Arnica Creeks over Chipmunk, Grouse, Clear, and Cub Creeks may be seen in table 3. It is suggested that the early season differential harvest of mature males in the northern lake areas of intense fishing pressure is the cause only for the differences that appear to exist between areas of the lake. Even at Grouse and Chipmunk Creeks, where fish are little affected by the early fishery a significant and constant excess of females in the spawning runs has been measured. This fact indicates that a differential mortality takes place prior to initial spawning. The reason may stem from differential natural mortalities to immature fish in the lake. Barnaby (1944) made note of the excess of females over males in the spawning runs of red salmon in Alaska. He attributed this condition partly to the selective action of the gill net fishery, but suggested that the principal cause underlying this condition lacked explanation. Foerster (1954), noting the same condition for the same species in British Columbia, also indicated that the selective action of the gill net fishery was partially the cause of the differential sex ratio in the spawning runs. He proposed, however, that since the sex ratio of seaward-migrating smolts was 1:1, as Barnaby had observed, the males had become more susceptible to natural mortality during ocean residence.

Weight loss and time spent upstream.— Additional insight into stream survival as it relates to loss in weight and time spent upstream can be obtained from table 15. Evidence from Arnica Creek shows that males remain in the stream for a longer period of time than females.

The males were upstream for an average of 17.3 days over a period of 4 years, while the year-to-year average varied from 12 to 20 days. The female, however, usually remained in the creek for 10 days, although averages for individual years ranged from 6 to 12 days. The average time difference between sexes was 7.3 days. The conclusion is that multiple servicing by males accounts for the difference, which is in keeping with the demands imposed by the unequal sex ratio. Because the average time spent in the stream by Arnica Creek adult females was 6 to 12 days, usually 10, and the reasoning that each must construct 3 redds during that period, it appears reasonable to assume that each female would construct a redd every 2 to 4 days and lay about one-third of her eggs in each redd.

In general, the measurements of weight loss and spawning time tabulated for other streams agree with those obtained at Arnica Creek. There appears to be no obvious relationship between the size of tributary and length of time spent in the stream for spawning. For instance, in 1950 when the sampling of natural spawners at Arnica and Chipmunk Creeks was comparable, an obvious time difference between the larger tributary and the smaller Arnica Creek was not detected. The tendency for males to remain in the stream for longer periods of time than females is evident from all other locations.

Stream-mortality estimates have been made in other trout investigations, and several authors have indirectly shown that survival of adults following spawning is rather low. Belding (1934) correlated the loss of weight associated with the prespawning and spawning period with the low percentage of repeat spawners in mature Atlantic salmon (*Salmo salar*). He inferred that the basic cause of the high mortality was purely physiological. The "natural depletion of the body tissues to the borderline of death by physiological starvation, the development of the sexual organs, and the expenditure of energy" results in a weakened condition and "on its return to the ocean that it is unable to undergo normal recuperation, or it becomes ready prey of its enemies." However, because of the time and distance involved in their spawning migration, Atlantic salm-

on lost a much higher percentage of body weight than did other salmonoids in other areas. Belding placed the lethal threshold of weight loss at 40 percent and calculated that Atlantic salmon lost from 31 to 44 percent during the reproductive period. These figures may be compared with 16.7 percent and 25.2 percent for male and female rainbow trout (Mottley, 1938), and 18.5 percent and 21.3 percent for male and female Yellowstone Lake cutthroat. However, this relatively small loss of weight by Yellowstone spawners may still be a delayed factor contributing to natural mortality.

Calhoun (1944), working with cutthroat trout (*Salmo clarki henshawi*) in Blue Lake, California, also suggested a close relation between weight loss during spawning and subsequent survival. He said, "Fish returning to the lake after spawning will have small opportunity to build up food reserves to tide them over the winter when the lake is frozen for six months." Calhoun based this supposition on his recognition of the small number of adult cutthroat which spawned a second time. Irving (1953), reporting on the ecology of the cutthroat (*Salmo clarki lewisi*) in Henrys Lake, Idaho, suggested a high rate of spawning and lake mortality on the basis of infrequent trap and fishing returns from marked spawners. While survival and mortality estimates were not presented, he did suggest that spawning loss was the result of injuries, disease, and exhaustion attributable to the activities leading up to and associated with reproductive activities.

Mottley, in his work with rainbow trout in the spawning runs out of Paul Lake, British Columbia, indicated that both the shedding of sex products and utilization of stored food materials were the cause of the loss of weight in males and females (16.7 and 25.2 percent). It was determined that the ovaries of the female constituted only 19 percent of the total body weight, and the testes of the male made up only 5 percent of its total body weight. Allowing for some retention of sex products by both sexes, Mottley estimated that the difference between the total loss of weight and that attributed to the actual loss of sex products, 9 percent for the female and 14 for the male, must be due to the utilization of stored food materials. Even though the female loses a greater percentage of her total body weight during spawning, it is the male who must draw upon a greater store of food reserves in order to survive this period.

Belding (1934) also found that female anadromous Atlantic salmon spawning under natural conditions lost significantly more weight per individual than those from which eggs had been taken by fish culturists. The difference, it must be assumed, can be attributed to the use of stored food materials by natural spawners. He indicated that the development of the eggs and sperm, expenditure of energy and cessation of feeding activities during spawning manifested themselves as stream death (spawning mortality), or as delayed mortality in the ocean as the delayed result of the spawning activities (lake mortality).

Stream mortality and time of migration.— Changes in the rate of stream mortality with the progress of the season were studied at Arnica Creek and viewed in the light of environmental factors which also changed throughout the season. The trout that entered Arnica Creek in early May were usually exposed to cold water and moderate stream flow conditions. These conditions gave way to heavier stream runoff, and the fish in the later parts of migration faced reduced stream flows and higher water temperatures. The trout responded to these changing conditions by changing their times spent in the stream, their distribution within the stream system, and their mortalities.

Table 12 presented the actual enumerations obtained at Arnica Creek traps from 1950 to 1953 and the corrected trap counts and estimated seasonal spawning mortalities derived therefrom. A more detailed analysis of spawning mortality involving

TABLE 16.—*Stream mortality and escapement to the fishery by the tag groups at Arnica Creek, 1950 to 1953*

[Fishing began on May 30 from 1950 to 1952 and on June 15 in 1953]

Time period	Number tagged-up (NT)	Number sampled down [$n(Td)$]		Number calculated down [$N(Td)$]		Group mortality (sm)	
		Group	Period	Group	Period	Percentage rate	Number
1950							
May 4–10	0						
May 11–17	0						
May 18–24	53	3	0	12		77	41
May 25–31	89	12	0	50		47	42
June 1–7	233	43	0	178		24	57
June 8–14	275	53	0	220		21	57
June 15–21	100	10	75	42	312	59	59
June 22–28	100	10	19	42	79	59	59
June 29–July 5	25	3	27	12	112	52	13
July 6–12	20	0	3	[1] 10	13	50	10
July 13–19	25	3	2	12	8	52	13
July 20–26	45	7	1	29	4	36	16
July 27–Aug. 2	0	0	7	0	29	0	0
Aug. 3–9	0	0	2	0	8	0	0
Aug. 10–16	0	0	6	0	25	0	0
Aug. 17–23	0	0	1	0	4	0	0
Aug. 24–30	0	0	1	0	4	0	0
Aug. 31–Sept. 6	0	0	0				
Sept. 7–13	0	0	0				
Season total	965	144	144	598	598	38.0	367
1951							
May 4–10	6	1		3		50	3
May 11–17	94	19		53		44	41
May 18–24	112	28		79		29	33
May 25–31	238	73	1	206	3	13	32
June 1–7	181	48	48	135	135	25	46
June 8–14	106	25	86	71	243	33	35
June 15–21	91	12	48	34	135	63	57
June 22–28	114	16	25	45	70	61	69
June 29–July 5	118	13	11	37	31	69	81
July 6–12	65	10	13	28	37	57	37
July 13–19	65	7	15	20	42	69	45
July 20–26	29	4	4	11	11	62	18
July 27–Aug. 2	23	3	7	8	20	65	15
Aug. 3–9	10	2	2	6	6	40	4
Aug. 10–16	0	0	1	0	3	0	0
Aug. 17–23	0	0	0				
Aug. 24–30	0	0	0				
Aug. 31–Sept. 6	0	0	0				
Sept. 7–13	0	0	0				
Season total	1,252	261	261	736	736	41.2	516
1952							
May 4–10	0	0					
May 11–17	0	0					
May 18–24	107	39	11	62	29	42	45
May 25–31	176	47	29	131	78	26	45
June 1–7	261	50	37	210	99	20	51
June 8–14	154	33	25	125	67	19	29
June 15–21	95	31	41	47	110	51	48
June 22–28	20	4	53	13	142	35	7
June 29–July 5	50	8	8	8	21	84	42
July 6–12	29	9	15	9	40	69	20
July 13–19	27	2	2	6	5	78	21
July 20–26	27	5	4	5	11	81	22
July 27–Aug. 2	12	4	5	4	13	67	8
Aug. 3–9	0	0	2		5		
Aug. 10–16	0	0					
Aug. 17–23	0	0					
Aug. 24–30	0	0					
Aug. 31–Sept. 6	0	0					
Sept. 7–13	0	0					
Season total	958	232	232	620	620	35.3	338
1953							
May 4–10	26	13	0	13	0	50	13
May 11–17	63	37	7	37	7	41	26
May 18–24	43	35	5	35	5	19	8
May 25–31	159	98	29	98	29	38	61
June 1–7	147	105	49	105	49	29	42
June 8–14	148	77	96	77	96	48	71
June 15–21	105	51	104	51	104	51	54
June 22–28	88	35	30	35	30	60	53
June 29–July 5	115	33	60	33	60	71	82
July 6–12	68	13	105	13	105	81	55
July 13–19	33	7	13	7	13	79	26
July 20–26	11	1	5	1	5	91	10
July 27–Aug. 2	2	0	2		2	100	2
Aug. 3–9	3	0	0			100	3
Aug. 10–16	5	1	0	1		80	4
Aug. 17–23	0	0	1		1		
Aug. 24–30	0	0	0				
Aug. 31–Sept. 6	3	0	0			100	3
Sept. 7–13	0	0	0				
Season total	1,019	506	506	506	506	50.3	513

[1] Estimated because of a lack of group sample.

tag group mortality rates at Arnica Creek is incorporated into table 16. This table lists the number of upstream tags, *NT*, which bear a constant proportional relation to the numbers of untagged members released upstream in each time period. Figure 4 demonstrates the relation between tag group mortality rates and mean maximum period temperatures at Arnica Creek.

The peak of each spawning run occurred when the mean maximum weekly temperature reached about 55° F. Movement of prespawners (trout approaching sexual maturity prior to spawning, in the lake or in the spawning migration) started at about 45° F. The peak of the run always preceded the period of highest daily water temperatures. Most of the fish for the season had passed upstream before the maximum daily temperature averaged 60° F. Maximum daily temperatures which exceeded 65° F. coincided with the occurrence of large numbers of dead spawners around the trap sites at Arnica and Pelican Creeks. The greatest difference in time between peaks of spawning and temperature occurred at Arnica Creek (5 weeks) and the smallest existed at Chipmunk Creek (1 week). This difference is related to the temperature characteristics of the individual streams, and particularly to temperatures associated with maximum movement of prespawners (53 to 57° F.).

The relation between the tag group spawning mortalities at Arnica Creek and thermal characteristics as reflected by the mean maximum weekly temperatures at the time the fish were enumerated at the upstream trap appears to be an intimate one. Typically, the early run of Arnica spawners suffers a high mortality, followed by a decrease in death rate at the time the peak of the run passes upstream. Thereafter, the group mortality rate increases rapidly, allowing few survivors to escape back into the lake from the terminal portion of the run. The high mortality experienced by the early run fish appears to be independent of the detrimental effects associated with excessive stream temperatures. During the latter half of the spawning runs, a relation between high mortalities and high water temperatures becomes apparent.

Spawners tend to spend less time in the stream as the season progresses. The early run may remain in Arnica as much as 2.0 to 2.5 times as long as the average spawner. Survivors of the last portion of the spawning migration usually spend about half as long in the stream as the average. These calculations are in agreement with the observations of Welsh (1952) and Cope (1956), who noted that the early Arnica Creek spawners characteristically utilized the spawning gravels in the upper portion of the stream. The main segment of the spawning run tended to distribute itself mostly in the middle and lower stream sections, and the late spawners concentrated nest building activities in that stream segment closest to the trap site. Although these late spawners travel the least distance upstream to spawn and spend the least amount of time in the stream itself, it is they who are subjected to the highest stream mortality. Length measurements show that the early portion of the Arnica Creek run is composed of the older and larger fish. The high spawning mortality characteristically incurred by these fish, while not related to adverse temperature conditions, may be attributable to a combination of causes. They may include age, length of time in the stream, and torrential runoff conditions. High water may induce physical injury and fatigue leading to death.

Effects of artificial spawning.—At Pelican Creek in 1950 both natural spawners and artificially stripped adults that had been thrown upstream from the trap after stripping were tagged. While both male and female artificially spawned fish remained in the stream for over a week, no difference between the two groups in time spent upstream was detected. No data are at hand to show why there was no immediate movement of hatchery-processed fish back into the lake. Possibly

it may be attributed to the retention of sex products not taken by the fish culturists, or to a period of recuperation from effects induced by handling. A marked difference between natural spawners and artificially spawned fish in average time spent in the stream was noted. Another important feature of this tagging procedure was the determination that artificially spawned fish lost less weight than did the other group.

Marking of 1,135 hatchery-spawned fish and 356 liberated for natural reproduction was also performed at Chipmunk Creek in 1950. The procedure resembled the Pelican Creek operation of the same year. At Chipmunk Creek, however, abundant tag-return data did not become available either from downstream sampling or from the fishery. Therefore, stream mortality for these two groups at Chipmunk Creek could not be reliably estimated. The indications from the ratios of tag returns from both groups collected from dead fish in the stream, the downstream sampling, Molly Island returns, and 1950–52 trap and fishery returns were that hatchery-processed fish had a better survival than did natural spawners.

This condition is in contrast with the results obtained in the identical operation at Pelican Creek. At the northern tributary where hatchery-processed fish were tagged uniformly throughout the spawning migration, their mortality was somewhat higher than that of the group released upstream for natural reproduction. It was calculated that the entire group of Pelican Creek natural spawners incurred stream mortality of 63 percent. The latter portion of this tag group, the late spawners, suffered an estimated 80 percent mortality. The stripped fish were tagged only during the latter part of the run. Their spawning mortality was measured as 94 percent, or 14 percent higher than the corresponding segment of the natural spawner group. Therefore, a combination of the high stream temperatures and multiple handling may well have affected this tag group more adversely than the natural spawners. The apparent reversal of this situation at Chipmunk Creek may best be explained by the predator and temperature relations. The lower water temperatures at Chipmunk Creek (table 2) may not have adversely influenced those fish handled for stripping and tagging purposes to the extent that presumably occurred at Pelican Creek. Because Chipmunk Creek fish released upstream for natural spawning stayed in the stream for a longer time than those released after stripping, their period of vulnerability to predation by pelicans was lengthened and the chance for capture was enhanced. Fish reproducing under natural conditions usually penetrate to shallower parts of the stream during migration and spawning, and thus become more available to the birds. Field observations have shown that adults before and during spawning activities react less to the approach of human beings and other animals than do postspawners. In agreement with the Pelican Creek results was the fact that Chipmunk Creek natural spawners spent from 2 to 3 times as long in the stream as did those that had been stripped.

Alternate and consecutive spawning.—The consequences of spawning may influence the number of postspawners that reproduce a second time. Belding (1934) found that less than 10 percent of Atlantic salmon returned from the sea to spawn a second time. Canadian Department of Fisheries' records were cited in the same report, giving a figure of 2.12 percent for return spawners. Vibert (1950) stated for the same species that a maximum of 3.8 percent of the mature fish he had worked with had spawned previously. Less than 10 percent of the cutthroat trout of Blue Lake, California, reproduced a second time (Calhoun, 1944). Tagging at Yellowstone demonstrated that an average of 1.22 percent of the spawning runs was composed of fish that had spawned before. As a rule, only 7 percent of the postspawners that survived the winter spawned again

TABLE 17.—*Summary of data on alternate and consecutive spawning, from repeat spawners entering traps in spawning streams, by years, 1950–55*

[A=number of tagged fish in the lake; B=number of fish returning; C=percentage of available spawners returning]

Stream and year of tagging	Returns to fish traps																				
	1950			1951			1952			1953			1954			1955			Total		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Arnica Creek:																					
1950	----	----	----	150	51	33.1	37	16	43.2	----	----	----	----	----	----	----	----	----	----	----	----
1951	----	----	----	----	----	----	193	12	6.2	51	9	17.6	----	----	----	----	----	----	----	----	----
1952	----	----	----	----	----	----	----	----	----	33	2	5.4	9	5	55.6	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----	----	----	----	----	204	20	9.7	53	9	17.0	----	----	----
Total, consecutive	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	580	85	14.7
Total, alternate	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	150	39	26.0
Pelican Creek:																					
1949	138	2	1.5	35	4	11.4	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1950	----	----	----	108	2	1.9	28	7	25.0	----	----	----	----	----	----	----	----	----	----	----	----
1951	----	----	----	----	----	----	232	5	2.1	57	17	29.8	----	----	----	----	----	----	----	----	----
1952	----	----	----	----	----	----	----	----	----	107	15	14.0	26	11	42.3	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----	----	----	----	----	227	16	7.0	55	9	16.4	----	----	----
Total, consecutive	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	812	40	4.9
Total, alternate	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	201	48	23.9
Clear Creek:																					
1953	----	----	----	----	----	----	----	----	----	----	----	----	182	2	1.1	47	5	10.6	----	----	----
Total, consecutive	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	182	2	1.1
Total, alternate	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	47	5	10.6
Grouse Creek:																					
1951	----	----	----	----	----	----	239	5	2.1	94	26	27.7	----	----	----	----	----	----	----	----	----
1952	----	----	----	----	----	----	----	----	----	42	6	14.3	11	2	18.2	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----	----	----	----	----	27	3	10.7	7	1	14.3	----	----	----
Total, consecutive	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	308	14	4.5
Total, alternate	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	112	29	25.9
Chipmunk Creek:																					
1949	317	6	1.8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1950	----	----	----	----	----	----	56	7	12.5	----	----	----	----	----	----	----	----	----	----	----	----
1952	----	----	----	(1)	(1)	(1)	----	----	----	25	3	12.0	7	4	57.1	----	----	----	----	----	----
1953	----	----	----	----	----	----	----	----	----	----	----	----	120	13	11.7	29	5	17.2	----	----	----
Total, consecutive	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	462	22	4.8
Total, alternate	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	92	16	17.4
All streams by tag group:																					
Consecutive	455	8	1.8	258	53	20.5	664	22	3.3	207	26	12.3	760	54	7.2	----	----	----	2,344	163	6.9
Alternate	----	----	----	35	4	11.4	121	30	24.8	202	52	25.7	53	22	41.5	191	29	15.2	602	137	22.8

[1] No trap maintenance in 1951.

the following year as consecutive spawners. Very few fish reproduced two years in succession. An estimated 22.8 percent of those few surviving through their second winter entered the spawning run for the second time. Rarely did an adult cutthroat spawn 3 years in succession.

In 15 cases where the return of spawners from a group of tagged fish was measured, alternate spawners outnumbered consecutive spawners in seven instances (table 17). A total of 300 tagged fish returned to the traps as repeat spawners, of which 137 (45.7 percent) spawned for the second time after a 2-year delay. There was always a greater percentage return of alternate spawners in terms of the number surviving. The consecutive spawners varied from 1.1 to 14.7 percent and averaged 6.9 percent of those available as spawners at the time. On the other hand, the number of alternate spawners ranged from 10.6 to 26.0 percent, averaging 22.8 percent. The returns to the various streams generally fluctuated equally about the mean from year to year.

The significance of this is that adult trout entering a tributary to Yellowstone Lake will seldom spawn a second time. Consequently, the runs are made up largely (always in excess of 90 percent) of fish spawning for the first time.

This alternate-consecutive spawning concept appears to have a physiological basis. The task for postspawners to regain sufficient food stores and an adequate physical condition to survive the winter is difficult. Presumably, during the winter they are almost completely dependent on an intrinsic source of food. In the Yellowstone environment, few postspawners would be physically able to develop sexually as consecutive spawners during this period of time. Even the following year

TABLE 18.—*Average mortalities and survivals in Arnica Creek spawning run of 1,000 spawners covering a period of 2 years, based on the history of spawning runs from 1950 to 1953*

Phase of life history	Mortalities (number of fish)			Survivals (number of fish)	Chronology	Age predominance
	Stream	Fishing	Lake			
Enter spawning run				1,000	May–June	III–IV–V
Spawning mortality	481					
Postspawners available to fishery				519		
Fishing mortality		60			June–Sept	
Natural mortality			319		June–May	
Adults surviving winter				140	May	IV–V–VI
Consecutive spawners				10	May–June	
Spawning mortality	5					
Alternate (non) spawners				130		
Adults available to fishery				135		
Fishing mortality		16			June–Sept	
Natural mortality			83		June–May	
Adults surviving winter				36	May	V–VI–VII
Accountability, in numbers of fish	486	76	402	36		
Percentage of original spawners	48.6	7.6	40.2	3.6		

finds only about 75 to 80 percent of the surviving fish capable of reproducing again.

The potential of repeat spawners is depicted in table 18. Beginning with a spawning run of 1,000 fish, average mortalities derived from stream locations, to be discussed later, are imposed. These data demonstrate that only 10 fish will function as consecutive spawners, and the potential alternate spawners number 42. Thus, the maximum number of fish spawning a second time, assuming that all of the potential alternate spawners will return to spawn, would not exceed 5.2 percent of the original 1,000 adults. The expected return of repeat spawners, however, would be about 2.4 percent (one-third of 5.2 percent, those available to spawn a second time).

The white pelican and the cutthroat.—The white pelican colony at Molly Island in the southeast arm of Yellowstone Lake is important in relation to trout in this drainage. It was "conservatively" estimated in 1922 that around 300,000 cutthroat trout were consumed annually by these piscivorous birds (Ward, 1922).[6] This figure may apply from year to year, since the number of pelicans breeding in Yellowstone Park seems to have remained rather stable for many years.

[6] Ward, H. B. The pelicans of Yellowstone Lake. Manuscript prepared for U.S. Bureau of Fisheries in cooperation with U.S. National Park Service, 1922. 20 pp.

Grinnell (1876) reported pelicans to be "very abundant" at the time of his visit in 1875. Skinner (1925) observed from 500 to 700 birds visiting the rookery annually from 1898 to 1917. In the summer of 1922, Ward estimated about 500 to 600 adults and 200 fledglings. Bird banding teams of the National Park Service from 1949 to 1951 estimated from 450 to 500 adult pelicans frequenting the islands annually. Biologists of the Fish and Wildlife Service counted more than 400 adult birds in 1953.

From 1924 to 1931 the pelican population was controlled by reduction in the number of eggs and adults. After control was terminated, Thompson (1932) reported only 300 adults and 100 young. Since 1932, the white pelicans have received complete protection. The public is forbidden to land or approach the two Molly Islands in the Southeast Arm. This breeding colony, therefore, is legally protected from exploitation, afforded protection from man by restricting of boat travel to the area, sheltered from mammal predation by virtue of the rookery's separation from the mainland, furnished a ready access from the nesting sites to the water for the young pelicans, and surrounded by an abundant supply of fish which become particularly available during the spawning migrations into tributaries of Yellowstone Lake. These con-

ditions favor survival of immature birds, and the perpetuation of the colony.

The first group of adult pelicans may arrive at Yellowstone Lake as early as May 1, and the rest of the colony will arrive in groups later in the month. The early arrivals begin their fishing activities along the Yellowstone River. Later, when the ice begins to leave the lake, the birds retire to the Molly Islands and begin breeding activities.

Two, occasionally one or three, eggs per nest are laid in May or early June. The incubation period is three or four weeks. The simply constructed nest are guarded by both parents, one at a time, at least during the incubation of the eggs and early rearing of the young. While one parent is away foraging for fish, the other parent remains on the nest. The morning flight has been observed to leave the Yellowstone rookery around daybreak and return around noon. The other parent then spends the afternoon fishing, returning to the nesting area around dusk. Feeding may continue into the night, as observed by Low, Kay, and Rasmussen (1950). Newly hatched pelicans feed upon the regurgitated fish offered by their parents. Growth is extremely rapid. The adult birds must not only satisfy their own enormous appetites, but those of the growing offspring. Studies at Molly Island indicate a third to a half of the total egg production survive to the fall as juvenile birds.

The feeding and nesting times of the adult pelicans at Yellowstone coincide precisely with the time that the mature cutthroat enter the spawning tributaries and become available to pelicans. Both parent birds have a limited time for foraging before returning to the rookery when the eggs are incubated and the young birds protected. This occurs when the trout are spawning. Hall (1925) appropriately suggested that "the white pelican eats the food most easily secured." During the 50 or 60 days of the movement of trout into tributaries of Yellowstone Lake, the pelicans prey almost exclusively upon this available and vulnerable fish. This view agrees with the field observations of Ward, who indicated that the white pelicans of Molly Island "were most abundant on streams where the spawning runs were the largest." Ward also estimated that Yellowstone trout made up 98 to 100 percent of the pelican's diet, particularly during the time of trout spawning.

Later in the season when the immature pelicans require less protection, both parent birds can be absent from the rookery for longer periods of time. The surviving trout have returned from the streams to the lake, and are less vulnerable to capture; consequently, the pelicans may feed in waters some distance removed from the Southeast Arm of Yellowstone Lake. Then, too, more time and effort may be devoted to obtaining mature and immature trout and suckers from shoal areas of the lake. Large flights of adult pelicans have been noticed leaving Yellowstone Lake in the late summer, presumably in a search for fishing grounds elsewhere (Skinner, 1925). Pelicans have been known to make daily flights of 100 to 150 miles to obtain their fish (Low, Kay, and Rasmussen, 1950).

The brown pelican (*Pelecanus occidentalis*) characteristically captures fish by diving from a considerable height directly onto the water. The white pelican fishes while on the surface of the water and obtains prey by rapidly plunging its head into the water. Pelicans are patient and efficient predators both in the streams and in the lake. Observers have seen them team up in a line and herd fish into shallow areas of Yellowstone Lake where capture was easier.

To estimate total mortality of trout from pelican predation, it is necessary to know at what rate fish are captured. Information on consumption rate and growth of young has been provided by Hall (1925) for white pelicans of Pyramid Lake, Nevada. The fledglings ate about half a pound of fish a day 10 days after hatching.

TABLE 19.—*Food consumption of the white pelican at Yellowstone Lake*

[In pounds of fish]

Number of pelicans	During a feeding day			During a 55-day spawning cycle			During a 100-day lake residence		
	Hall	Ward	Average	Hall	Ward	Average	Hall	Ward	Average
1	4	11	7.5	200	605	412	400	1,100	750
100	400	1,100	750	22,000	60,500	41,200	40,000	110,000	75,000
200	800	2,200	1,500	44,000	121,000	82,400	80,000	220,000	150,000
300	1,200	3,300	2,250	66,000	181,500	123,600	120,000	330,000	225,000
400	1,600	4,400	3,000	88,000	242,000	164,800	160,000	440,000	300,000
500	2,000	5,500	3,750	110,000	302,500	206,000	200,000	550,000	375,000
600	2,400	6,600	4,500	132,000	363,000	247,200	240,000	660,000	450,000
700	2,800	7,700	5,250	154,000	423,500	288,400	280,000	770,000	525,000

A month after hatching, their consumption had increased to 2 pounds of fish each day. At this time, the down-covered birds weighed 6 to 7 pounds. Fifteen days later, 55 days after hatching, they had attained weights of 10 to 12 pounds, and their daily food consumption had doubled. The first flight trials occurred around the 63d day, at which time each surviving offspring had accounted for a total of 150 pounds of fish. They then weighed 12 to 13 pounds and exhibited appetites characteristic of adult birds.

Hall's estimate of the consumption rate for adult birds is 4 pounds of fish per day. He stated, however, that "pelicans frequently fish until the esophagus up to the mouth is filled and greatly distended." Bent (1922) often observed a captive white pelican consuming 6 to 8 pounds of food at a single meal. In a tributary to Yellowstone Lake, Ward witnessed a rate of capture of 2 adult fish per hour. Fishing at least 6 hours per day during the first 2 months at the rookery, each parent bird would take about 12 fish (10 to 12 pounds) per day. A portion of the food taken, of course, would be fed to the fledglings. From these data, Ward's mortality estimate of 300,000 adult trout was computed only through the 50-day spawning cycle of the fish. The rest of the time spent fishing by the pelicans was not included; hence, his estimate was considered to be minimal. The utilization rates by white pelicans at various population levels and using consumption rates of Hall, Ward, and a mean rate of 7.5 pounds per day have been consolidated in table 19. Consumption is given in pounds, and conversion to fish numbers is accomplished by using a factor of 1.14, a figure derived from average weights of adult fish in the population.

Immature pelicans are fed by their parents for about 75 days at Molly Island; that is, to the time of southward departure in early September. Since each fledgling consumes approximately 150 pounds of fish during the first 63 days and with a low daily consumption rate of 4 pounds thereafter, each bird-of-the-year requires almost 200 pounds of food to the time of migration. Assuming these fish to be adult cutthroat trout from Yellowstone Lake, then the 200 young reared at Molly Island in 1953 alone accounted for at least 40,000 trout.

Yellowstone Lake and its tributaries are favorable for pelican feeding. Not only are cutthroat trout the principal inhabitants of the lake, but they become highly vulnerable to pelicans and other predators during temporary stream residence as spawners. In a single day a population of 500 adult pelicans may capture 3,750 pounds of fish (4,275 adult trout). During the 55-day spawning cycle of the trout, the same number of birds can account for 234,840 fish. Even Hall's minimal consumption rate extended over this 2-month period totals 125,400 trout. Regardless of which consumption rate is most appropriate, there is little doubt that the white pelican is the principal animal predator on adult cutthroat trout at Yellowstone

TABLE 20.—*Record of tag recoveries, 1949 to 1954*

[Numbers in parentheses denote returns from stream fishing other than Yellowstone River]

Tag group	Number of fish tagged	Numbers of tags recovered												
		1949		1950		1951		1952		1953		1954		
		Fishery	Molly Island	Fishery	Molly Island	Fishery	Molly Island	Fishery	Molly Island	Fishery	Molly Island	Fishery	Molly Island	Total
1949:														
Chipmunk Creek	649	11	28	35	0	0	0	0	0	0	0	0	0	74
Pelican Creek	750	27(4)	33	14(2)	0	0	0	0	0	0	0	0	0	80
1950:														
Chipmunk Creek	1,491	----	----	19	30	12	0	1	0	0	0	0	0	62
Pelican Creek	2,200	----	----	54(15)	20	9(2)	0	1	0	0	0	1	0	102
Arnica Creek	965	----	----	44	0	17	0	2	0	0	0	0	0	63
1951:														
Grouse Creek	1,196	----	----	----	----	29	11	15	0	0	0	0	0	55
Pelican Creek	1,295	----	----	----	----	75(20)	2	28(3)	0	1	0	0	0	129
Arnica Creek	1,252	----	----	----	----	82	3	12	0	0	0	0	0	97
Yellowstone River	399	----	----	----	----	89	1	22	0	7	0	1	0	120
1952:														
Chipmunk Creek:														
Up	408	----	----	----	----	----	----	2	27	0	0	0(2)	0	31
Down	125	----	----	----	----	----	----	9	0	2	0	0	0	11
Grouse Creek:														
Up	492	----	----	----	----	----	----	3	49	2	0	0	0	54
Down	202	----	----	----	----	----	----	2	0	1	0	6	0	9
Pelican Creek:														
Up	744	----	----	----	----	----	----	72(11)	5	13(1)	0	7	0	109
Down	167	----	----	----	----	----	----	20(2)	1	1	0	0	0	24
Arnica Creek	958	----	----	----	----	----	----	40	9	3	0	7	0	59
Yellowstone River	400	----	----	----	----	----	----	71	0	24	0	1	0	96
Trap net	454	----	----	----	----	----	----	63	0	20	0	2	0	85
Southeast arm	265	----	----	----	----	----	----	1	0	0	0	0	0	1
1953:														
Chipmunk Creek:														
Up	440	----	----	----	----	----	----	----	----	11	22	7	0	40
Down	112	----	----	----	----	----	----	----	----	5	1	1	0	7
Grouse Creek:														
Up	431	----	----	----	----	----	----	----	----	5	28	2	0	35
Down	172	----	----	----	----	----	----	----	----	7	0	0	0	7
Pelican Creek:														
Up	1,246	----	----	----	----	----	----	----	----	114(7)	4	30(1)	0	156
Down	77	----	----	----	----	----	----	----	----	2	1	1	0	4
Arnica Creek:														
Up	1,019	----	----	----	----	----	----	----	----	40	3	12	0	55
Down	353	----	----	----	----	----	----	----	----	29	3	5	0	37
Yellowstone River	379	----	----	----	----	----	----	----	----	78	1	9	0	88
Trap net	275	----	----	----	----	----	----	----	----	68	0	11	0	79
Clear Creek:														
Up	497	----	----	----	----	----	----	----	----	24(5)	1	11	0	41
Down	595	----	----	----	----	----	----	----	----	19	1	4	0	24
Total	20,008	38(4)	61	166(17)	50	313(22)	17	364(16)	91	476(13)	65	108(3)	0	1,834

Lake. Animal predation probably has always accounted for more trout than has the sport fishery.

The return of fish tags from fecal deposits on Molly Island gives an indication of the area and relative impact of pelican activity, although not all tags are returned to the rookery (see table 20).

These data demonstrate that pelicans concentrate their fishing largely in the southern part of the lake. Chipmunk and Grouse Creeks provided greater numbers of recovered tags than did other tagging locations, as illustrated in figure 5. Field observations over a period of several years have detected large concentrations of these birds to be associated with the spawning runs of the larger tributaries in the South and Southeast Arms. The large number of Pelican Creek tags recovered from the rookery in 1949 may be related to the unusually large spawning run that entered the stream that year.

All Arnica Creek tags that were recovered on the Molly Islands came from fish that had been checked through the downstream trap, suggesting that lake predation is probably characteristic for postspawners from stream areas farthest removed from Molly Island. In general,

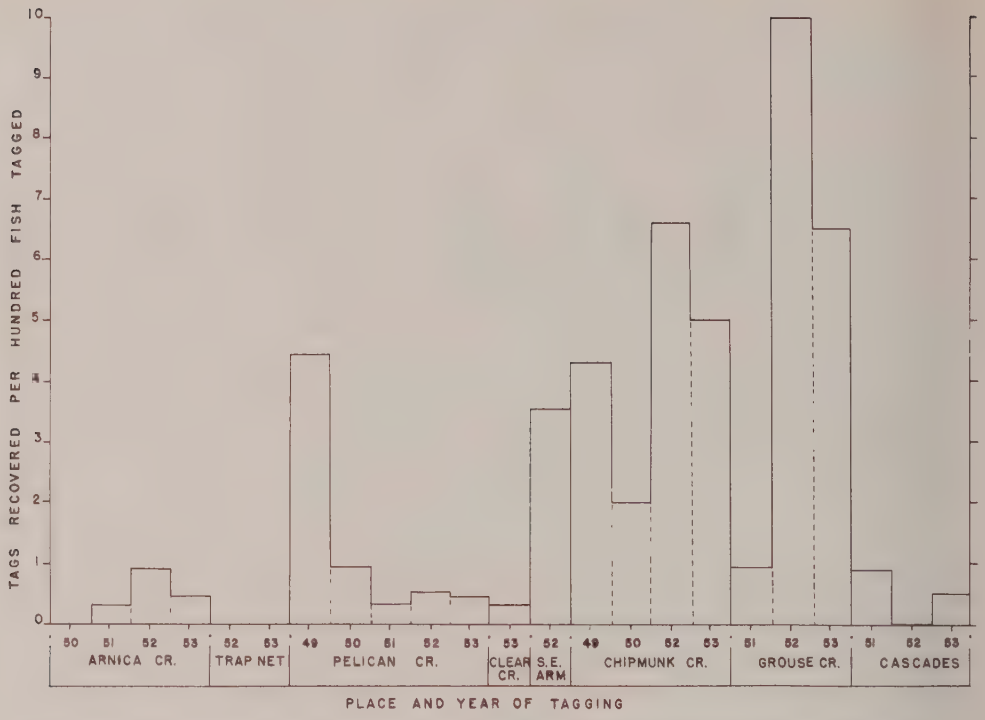

FIGURE 5.—Results of tag collections from the pelican rookery at Molly Island, 1949–53.

stream predation predominates in the southern half of Yellowstone Lake, and especially in the larger tributaries.

Increased vulnerability of fish with bright-colored tags to pelican predation, as compared with those without tags, has been considered in these studies. Of the 2,203 tags applied at Pelican Creek in 1950, 1,878 were yellow and 325 were dull green. The subsequent returns from Molly Island totaled 20 and consisted of 17 yellow and 3 green tags. Thus, where tags of two colors of different degrees of brightness were applied at a single location, the two colors were apparently taken by pelicans at about the same rate. No estimate of increased susceptibility to capture due to the presence or absence of a tag, or to any difference between bright-yellow and dull-green tags, is available.

The recovery of fish tags from the white pelican rookery at Molly Island, and ecological studies on this bird and the fish population, bear out the following conclusions: (1) The principal animal predator of the trout of Yellowstone Lake is the pelican, which draws its toll principally from mature fish in May, June, and July; (2) total natural mortality inflicted by pelicans presently exceeds the mortality resulting from the sport fishery; (3) the spawning runs of the southern part of the lake are most seriously affected where these birds forage principally at the mouths of larger tributaries and on the spawning gravels; (4) fish in the northern and West Thumb sections of Yellowstone Lake are relatively little affected, and stream fishing by pelicans there is more common than is lake fishing; (5) although pelicans may frequent the upper Yellowstone River and its tributaries in large numbers, the river below fishing bridge is visited by relatively small numbers of birds throughout the season; and (6) the take of fish by the pelicans appears to be a combined function of

availability of fish, proximity of fishing areas to the rookery, size of stream or depth of lake, and amount of human activity in the area.

Summary of mortality associated with spawning.—The conditions that influence spawning mortality of cutthroat trout may be summarized as follows:

1. Of adult fish migrating into tributaries of Yellowstone Lake, more than 90 percent are initial spawners between 3 and 5 years of age.

2. Time spent in the stream by both sexes varies during the spawning run, and appears to depend on aquatic conditions. Males usually remain upstream longer than females. This is at least partly due to the numerical dominance of females in the runs, necessitating multiple servicing by males.

3. The total loss of body weight (sex products and stored fat and muscle) by females exceeds that by males, but the males lose a greater percentage of fat and muscle than the females, probably because of greater activity and a longer time in the stream. Under adverse conditions the mortality of male spawners may be higher than that of females. An equal stream mortality for both sexes can be expected under normal conditions.

4. The rate of stream mortality varies widely from stream to stream in any given year, and in the same stream from year to year.

5. Sources of natural mortality in the stream differed from area to area. The aquatic environment was warmest at Pelican and Arnica Creeks, and the rate of spawning mortality was highest when the stream temperature reached a peak. At Arnica Creek, crowding due to the relatively large spawning run for the stream size made spawners more vulnerable to predation by bears. At Pelican Creek, where the distance to the spawning gravels was much greater, pollution from geyser basins and hot mineral springs materially contributed to greater year-to-year fluctuations in stream mortality. Grouse and Chipmunk Creeks support a more favorable stream condition. Here, deaths in the stream are largely attributable to predation by pelicans. The proximity of both streams to the rookery at Molly Island. the limited human activity in the area, and the sizes of the tributaries and spawning runs give the birds ready access to the spawning fish. At all locations, stream predation by pelicans, bears, and other fish-eating animals account for an unknown number of spawners before, during, and after egg deposition. In the Fishing Bridge spawning area, the fishermen hold the same relation to the mature fish. However, even if activities of natural and human predators were nonexistent, and if aquatic conditions were ideal, a significant spawning mortality should nevertheless occur. The tagging operation at Clear Creek, a stream which most closely approaches such an ideal condition, supports this view.

6. Natural mortality in the stream itself, subsequent survival, and a seldom-realized second spawning are functions of the physical condition and activities of the adults before and after spawning. During the year following spawning, natural mortality accounts for about 60 percent of those that survive and return to the lake. These deaths are assumed to be greatest during the ensuing winter. The inability of postspawners to regain an adequate physical condition during the summer's feeding to meet the biological demands of the severe winter environment that follows may largely determine natural mortality in the lake.

7. The conclusion that few trout spawn in consecutive years has a sound physiological basis. Postspawners are seldom in a condition to mature sex products for the next year and at the same time maintain themselves through the winter. Hence, the following summer must also be used for recuperation. Some are then able to function the second spring as alternate spawners. However, natural mortality through the postspawning period reduces

the numbers of surviving adults so greatly that few are available to spawn again.

Fishing mortality of postspawners

Efficiency of tag recoveries in 1953.—A roadblock interview with fishermen was made to obtain data pertaining to tag-recovery efficiency. Table 21 shows that of the 35 tags located in the interviews, it was decided that 4 would not have been turned in. Two of the six tags that had not been turned in before the interviews were considered to be tags that would have been returned. The remainder of the contacted tags (29) had already been checked in. This return of 31 out of 35 tags suggested that 11.4 percent of the tags from fish actually caught by the fishermen might not be returned.

Lake fishing.—Studies on fishing mortality in Yellowstone Lake were carried on in several ways, with tagging as a tool to relate numbers of fish caught by fishermen to numbers previously released from traps in streams or into the lake. Fish released from trap nets into the lake became immediately available to fishermen, but those trapped in streams often were delayed in their entrance into the catch. Most fish taken in lake traps were intercepted on their way to spawning areas near Fishing Bridge; those released downstream from stream traps had completed their spawning. The methods of analysis of contributions to the catch from these populations varied according to the circumstances at the several locations.

TABLE 21.—*Tag-return efficiency, as determined from the road-block interview, 1953*

Date	Number of persons interviewed	Number who fished	Number of tags			
			Total	Turned in	Would have been turned in	Not turned in
June 21	2,687	280	0	0	0	0
28	1,581	345	2	2	0	0
July 5	2,094	371	4	4	0	0
12	1,757	354	1	1	0	0
19	4,007	686	12	7	2	3
26	1,791	363	7	6	0	1
Aug. 2	2,534	194	1	1	0	0
9	1,906	283	4	4	0	0
16	3,613	436	3	3	0	0
23	1,149	127	0	0	0	0
30	1,282	116	1	1	0	0
Sept. 6	1,630	132	0	0	0	0
Total	26,031	3,687	35	29	2	4

The methods employed in this report differ in detail and application, but not in principal, from those of Graham (1938). The effect of the fishery on a stock of marked fish may be analyzed from an instantaneous or rate-of-fishing standpoint and as a seasonal rate, termed fishing mortality.

The rate of fishing uses the tag returns for each tagging location during a time period and expresses them as a percentage of the cumulative availability of that particular group of tagged fish. Since tagging and escapement to the fishery occurred before and during the period of most intense fishing, the number of tagged fish liberated into the lake was accumulated (less prior tag returns) to the end of each time period (cumulative availability). Analysis was based on the accumulation of nonaccountable tags throughout the season. No correction was made for concurrent natural mortality throughout the fishing period. The rate of fishing can be assumed to approximate the degree of exploitation affecting that population of adult fish at any given time.

Fishing rate is also given as period fishing returns or rate of tag return. This measure presents the results from limited data as comparable with data from more extensive experiments where the rate of fishing analysis was used. Period returns expresses the number of tags returned within a weekly time period as a percentage of the total for the season for each group of tagged fish.

Two independent measures of seasonal fishing mortality are used. One, tag group fishing mortality, is computed from the total tag returns per season in relation to the total number exposed to the fishery. A tag group includes the number of fish tagged during a time period. Therefore, only the survivors of each tag group become

exposed to the fishing pressure. This measure of fishing depends on precise information about stream mortality rates, and was used only for Arnica Creek from 1950 to 1953. The period of stream habitation and the time of tagging, exposure to the fishery, and general physical condition of postspawners varies for each tag group throughout the season. These variables determine when and how many postspawners enter the lake.

The second measure of seasonal fishing mortality, time group fishing mortality, deals with the total number of tagged fish (time group) checked downstream into the lake during a time period. This fishing mortality expresses the number of tagged fish taken by fishermen during the season as percentage of the appropriate time group. A time group originates by a complete count of a downstream run containing tagged fish (Arnica Creek, 1953). If tagging of postspawners takes place, the number marked each week is also a time group (Arnica Creek, 1953; Pelican Creek, 1952–53; Chipmunk and Grouse Creeks, 1952–53; Clear Creek, 1953).

The principle difference between these two methods lies in group identification. Fishing mortality for all marked fish averaged through the entire fishing season was used at most stream locations because tagging procedures were of a less precise nature than those used at Arnica Creek.

The tagging operations at the Cascades and trap net could not differentiate tag and time groups; consequently, they are identical.

The sparse fishery tag returns from Chipmunk and Grouse Creeks necessitated the combining of measurements of fishing intensity for the two locations in 1952 and 1953. This procedure was considered valid because the streams are located only a few miles apart, and the characteristics of their spawning runs and the subsequent tag returns from the fishery were similar in pattern.

Arnica Creek from 1950 through 1953 provided the most complete mortality data for any stream location. Stream mortality data have been summarized previously both in text and appendix tables. Measurements of fishing intensity for Arnica Creek are summarized in table 22. The complete data from which this summary was prepared appear in appendix tables 1 and 2.

TABLE 22.—*Measurements of fishing intensity on fish tagged at Arnica Creek, 1950–53*

Time periods	Tag group fishing mortality (number of fish)				Time group fishing mortality (number of fish) 1953	Rate of fishing (percent of fish available)				Period returns (number of fish)			
	1950	1951	1952	1953		1950	1951	1952	1953	1950	1951	1952	1953
May 4–10	------	0	------	15	----------	------	------	------	------	------	------	------	------
May 11–17	------	23	------	11	14	------	------	------	------	------	------	------	------
May 18–24	33	13	11	6	0	------	------	------	------	------	------	------	------
May 25–31	6	13	10	11	16	------	------	------	------	------	------	------	------
June 1–7	6	6	6	10	12	------	0.0	0.0	------	------	------	------	------
June 8–14	4	10	4	4	10	------	1.3	1.8	------	------	6	13	------
June 15–21	10	15	2	12	13	0.0	1.6	1.6	1.9	0	10	15	13
June 22–28	20	16	0	3	6	0.5	2.1	1.0	0.8	5	15	13	6
June 29–July 5	17	8	0	0	9	2.4	1.7	1.3	1.5	27	12	18	13
July 6–12	20	7	11	0	1	1.4	1.1	1.4	0.9	16	9	20	10
July 13–19	17	5	17	0	0	1.2	1.8	0.4	1.0	14	15	5	12
July 20–26	0	0	0	0	0	1.0	1.7	0.4	1.1	11	13	5	13
July 27–Aug. 2	------	0	0	0	0	0.6	0.3	0.2	1.4	7	2	2	16
Aug. 3–9	------	0	------	------	0	0.6	0.9	0.0	1.0	7	7	------	12
Aug. 10–16	------	------	------	0	----------	0.5	0.6	0.5	0.3	7	5	8	3
Aug. 17–23	------	------	------	------	0	0.2	0.3	0.2	0.3	2	2	2	3
Aug. 24–30	------	------	------	------	0	0.2	0.3	0.0	0.0	2	2	------	------
Aug. 31–Sept. 6	------	------	------	------	0	0.2	0.2	0.0	0.0	2	1	------	------
Sept. 7–13	------	------	------	------	----------	0.0	0.0	0.0	0.0	------	------	------	------
Total number	------	------	------	------	----------	------	------	------	------	44	82	40	69
Average (percent)	7.4	11.1	6.5	7.9	8.0	------	------	------	------	------	------	------	------

The run of adult fish into Arnica Creek usually begins early in May and reaches a peak later in the month or in early June. During 4 years of investigation, more than two-thirds of the Arnica postspawners entered the lake each year between June 1 and July 12. Between 7.3 and 12.4 percent of the tagged fish were later caught by the fishermen. Fishing mortality for individual tag groups ranged as high as 33 percent. The tag groups entering the stream earliest are usually more efficiently harvested than are those tag groups from the latter part of the spawning run. Time group fishing mortalities in 1953 produced rates in keeping with those estimated for tag groups.

Arnica Creek fish were most efficiently harvested by fishermen after the first week in June through the middle of July, as indicated by the rate-of-fishing estimates. As an average, the rate of fishing equaled or exceeded 1.0 for a period of 5 or 6 weeks each season. After the middle of July, the fishery for Arnica Creek postspawners declined markedly. Year-to-year variations in distribution of fishing rates within the season are evident, although the success with which they are harvested for an entire season appears to be quite stable.

Period returns demonstrated that the catch of Arnica Creek fish was well distributed thoughout the fishing season. Over half of the tagged fish were taken from the last week in June through the end of July. In 1950, the period of June 29 through July 5 was the week of most successful fishing (rate of fishing, 2.4) and the week of the greatest number of tag returns (27 percent of the total returns at that time). However, in 1952 the most efficient catch took place from June 8 to June 14, and the greatest number of postspawners was taken during the period from July 6 to July 12.

Usable rates of fishing were also obtained from Pelican Creek for 1952 and from Chipmunk and Grouse Creeks combined for 1952 and for 1953 (table 23). The complete information pertaining to this summary can be studied in appendix tables 3 and 4. The most efficient fishing for Pelican Creek fish took place from July 20 to July 26. The rate of fishing was 3.2 and compares with maximum values of 1.8 for Arnica Creek and 1.7 for Chipmunk and Grouse Creeks for the same year. Pelican Creek sustained a fishing rate of 1 or greater over a period of 5 weeks, as did Arnica Creek the same year. Chipmunk and Grouse Creeks supported comparable rates for only 2 weeks in 1952 and 1 week in 1953.

TABLE 23.—*Rates of fishing obtained from tagging at Pelican Creek for 1952 and at Chipmunk and Grouse Creeks for 1952 and 1953*

[Expressed as number of tagged fish captured per 100 available during each time period]

Time period	Rate of fishing in—		
	Pelican Creek 1952	Chipmunk and Grouse Creeks 1952	Chipmunk and Grouse Creeks 1953
June 15–21	0.0	0.0	----------
June 22–28	0.0	0.0	----------
June 29–July 5	0.6	0.0	0.0
July 6–12	3.0	1.3	0.0
July 13–19	1.9	0.0	0.0
July 20–26	3.2	1.7	0.0
July 27–Aug. 2	1.3	0.6	0.7
Aug. 3–9	0.7	0.9	1.8
Aug. 10–16	2.0	0.3	0.7
Aug. 17–23	0.0	0.0	0.7
Aug. 24–30	0.0	0.0	0.0
Aug. 31–Sept. 6	0.0	0.0	0.4
Sept. 7–13	0.0	0.0	0.0

The only measurement of fishing intensity furnishing a comparison between all tagging operations throughout the program is the period fishing returns. A summary of first-year returns (tagged fish caught the same year as tagged) for each tagging location averaged for all years is seen in table 24. Supplemental data pertaining to period tag returns, which includes information concerning second-year tag returns (tagged fish caught the year after tagging), may be found in appendix tables 5 and 6. A general resume of all first and second year tag returns is included in appendix table 7.

Considering all areas combined, 70 percent of all available tagged fish were taken by fishermen in the month of July. More marked fish from the Cascades and

TABLE 24.—*Summary of first-year period fishing returns for various years from all tagging locations*

[Expressed as percentage of total returns for each stream]

Time period	Period tag returns from—						All areas
	Arnica Creek 1950–53	Pelican Creek 1949–53	Clear Creek 1953	Chipmunk and Grouse Creeks 1949–53	Cascades 1951–53	Trap net 1952–53	
June 1–7		0.3			1		0.4
June 8–14	4	2		1	0.4		2
June 15–21	10	2	2		3		3
June 22–28	10	3	2	1	6	6	5
June 29–July 5	16	10	2	2	26	29	16
July 6–12	12	13	9	4	23	26	16
July 13–19	12	10	9	7	18	22	13
July 20–26	11	21	19	15	12	8	15
July 27–Aug. 2	7	14	16	18	5	5	10
Aug. 3–9	7	10	23	16	2	2	8
Aug. 10–16	5	7		17	1	1	5
Aug. 17–23	3	4	14	12	1		4
Aug. 24–30	1	4	2	2			2
Aug. 31–Sept. 6	1			4	0.4		1
Sept. 7–13				3	.4		.4
Total number of returns	235	364	43	103	238	129	1,112

trap net were caught during the opening week of the river fishery (July 1) than in any other week. Clear, Chipmunk, and Grouse Creeks were characteristically late (July or early August) in contributing fish to the creel.

The effects of fishing on tagged fish from the trap net (table 25) reveal some important contrasts with stream locations. Fishing mortality was several times greater than those estimated for tributary post-spawners. All tag (or time) groups for the trap net sustained heavier fishing mortalities. This was especially true for the tag groups marked during the height of the Fishing Bridge area fishery, from June 22 to July 15 in 1952 and 1953. The rates of fishing demonstrate that although the fishery for trap net fish was of short duration, the success was very high. A short time between tagging and capture is indicated by the period returns. An average of 79 percent of the trap net fish taken by anglers were caught between June 29 and July 19. Seasonal fishing mortality sustained by trap net fish averaged 21 percent. During the week when fishing was most successful, from 7.9 to 14.1 adult trout per 100 available were caught by anglers. Additional information relating to the trap net tagging operation is included in appendix tables 8 and 9.

TABLE 25.—*Measurements of fishing intensity on fish from the trap net, 1952 and 1953*

Time period	Tag/time group fishing mortality (number of fish)		Rate of fishing (percent of fish available)		Period returns (number of fish)	
	1952	1953	1952	1953	1952	1953
June 15–21	0	33		0.0		
June 22–28	25	31	4.5	2.9	8	4
June 29–July 5	28	28	7.1	14.1	18	40
July 6–12	21	14	7.9	7.9	28	25
July 13–19	2	13	5.3	6.5	25	21
July 20–26	8	10	2.0	1.9	10	6
July 27–Aug. 2			1.3	1.0	7	3
Aug. 3–9			.7	.5	3	1
Aug. 10–16			.3	.0	2	
Total number					61	68
Average (percent)	17.3	24.7				

In 1952, 101 fish tagged at the trap net were considered to be immature, that is, were under 300 mm. in total length and did not appear to be gravid. Only two tags from this group were returned by fishermen in 1952. The fishing mortality of 2.0 percent for immature fish, when compared with 17.3 percent for the adult trout, indicated that availabilities of both tag groups were not comparable or that the fishery was selective. Only 5 tags from this immature fish group were taken in 1953 and none in 1954. Considering the mortality estimates for trap net fish tagged in 1953, it was obvious that an extrinsic mortality was imposed on the smaller fish in 1952. Full recruitment into

the fishery was contemplated in 1953 and 1954, but it did not occur. Possibly the the handling and tagging of smaller fish was detrimental and resulted in delayed mortality after being released. This group was separated from the adult fish for purposes of analysis.

Fishing-intensity measurements for fish tagged at the Cascades of the Yellowstone River (table 26) show results similar to those obtained from the trap net operation. Estimates of fishing mortality for "lake" and "river" fish indicated comparable magnitudes. The first week in July was also the time when river fish were most efficiently taken by anglers. However, the fishermen began catching Cascades fish several weeks before the trap net fish, because of the earlier spawning run in the river. The harvest was also more prolonged, as demonstrated by the period returns and fishing rates. Adult fish from the Cascades and trap net were caught in greatest numbers when the river and Fishing Bridge opened to the anglers. Appendix tables 10 and 11 contain additional information pertaining to the Cascades tagging operation.

The actual return of tags from angler-caught fish is estimated to be about 88.6 percent of the actual take of tagged fish, based on a program of interviewing fishermen in 1953. Corrected mortalities for the season (table 27) did not modify the results on a relative basis. However, this refinement is valuable when used in absolute computations. For instance, when computing the contribution of postspawners to the lake fishery (table 28), the use of corrected fishing mortalities gives a more realistic measure of value.

Two methods of computing spawning mortality were available for Arnica Creek in 1953 (table 11). The actual count (method 1) was used rather than the estimate (method 2), in this instance. A measure of the reliability of estimate was provided, however. Two methods were used at Pelican Creek in 1952, and the results represent an average mortality figure derived from the two estimates.

The application of data from table 29 provides a measure of the contribution of

TABLE 26.—*Measurements of fishing intensity on fish from the Cascades, 1951 to 1953*

Time period	Tag/time-group fishing mortality (number of fish)			Rate of fishing (percent of fish available)			Period returns (number of fish)		
	1951	1952	1953	1951	1952	1953	1951	1952	1953
May 25–31	----	18	----	----	----	----	----	----	----
June 1–7	----	19	0	----	2.7	----	----	4	----
June 8–14	16	17	17	0.0	0.4	----	----	1	----
June 15–21	22	18	9	1.6	1.6	0.0	2	7	----
June 22–28	33	16	27	1.1	1.8	3.4	2	10	8
June 29–July 5	----	20	20	10.6	5.7	8.6	21	31	28
July 6–12	22	----	22	6.6	4.1	5.2	25	21	23
July 13–19	20	----	17	7.1	1.2	4.2	28	6	18
July 20–26	----	----	0	3.3	2.0	3.1	12	10	13
July 27–Aug. 2	----	----	----	1.9	.6	1.0	7	3	4
Aug. 3–9	----	----	----	.3	.3	.7	1	1	3
Aug. 10–16	----	----	----	.3	.3	.3	1	1	1
Aug. 17–23	----	----	----	.0	.3	.7	----	1	3
Aug. 24–30	----	----	----	.0	.0	.0	----	----	----
Aug. 31–Sept. 6	----	----	----	.0	.3	.0	----	1	----
Sept. 7–13	----	----	----	.0	.3	.0	----	1	----
Total number	----	----	----	----	----	----	89	71	78
Average (percent)	22.3	17.8	20.6	----	----	----	----	----	----

TABLE 27.—*Seasonal fishing mortalities based on an 88.6-percent tag-return efficiency*

Stream and year	Uncorrected fishing mortality	Corrected fishing mortality
Arnica Creek:	*Percent*	*Percent*
1950	7.4	8.4
1951	11.1	12.6
1952	6.5	7.3
1953	8.0	9.1
Average	8.3	9.4
Pelican Creek:		
1949	10.4	11.6
1950	10.3	11.6
1951	8.3	9.4
1952	12.2	13.8
1953	13.5	15.2
Average	10.9	12.3
Clear Creek:		
1953	8.4	9.4
Grouse Creek:		
1951	4.3	4.9
1952	1.2	1.5
1953	4.0	4.7
Average	3.2	3.7
Chipmunk Creek:		
1949	2.2	2.4
1950	4.2	4.9
1952	7.5	8.2
1953	4.8	5.4
Average	4.8	5.2
Trap net:		
1952	17.3	19.5
1953	24.7	28.0
Average	21.0	23.8
Cascades:		
1951	22.3	25.1
1952	17.8	20.0
1953	20.6	23.2
Average	20.2	22.7

postspawners from various streams to the sport fishery of the lake (table 28); the surviving number from each spawning run is listed in column 2. When treated with the corrected seasonal fishing mortality figures, the total catch from each stream follows. When the total contribution from each individual stream or the sum for all streams is related to the total lake harvest for the year, the importance of postspawners in the sport fishery is obvious. At no time did the harvest from any individual stream amount to 1 percent of the lake catch. The most sizable contribution by any stream location was 1,297 postspawners from Pelican Creek in 1953, which amounted to only 0.66 percent of the total catch in the lake that year. In 1953 when measurements were made on fish from five streams, their combined totals (2,471 fish) were less than 2 percent of the 195,873 trout estimated to have been taken by fishermen.

TABLE 28.—*Contributions to the lake fishery by the postspawners from several streams, 1949 to 1953*

Stream and tag year	Available to fishery (number)	Corrected fishing mortality (percent)	Contribution to lake fishery	
			Number	Percent
Arnica Creek:				
1950	2,534	8.4	213	0.11
1951	3,220	12.6	406	.19
1952	2,528	7.3	185	.08
1953	2,462	9.0	222	.11
Pelican Creek:				
1949	11,286	11.6	1,309	.65
1950	5,910	11.6	686	.34
1951	6,671	9.3	620	.30
1952	5,152	13.8	711	.29
1953	8,648	15.0	1,297	.66
Chipmunk Creek				
1949	10,457	2.4	251	.13
1950	4,203	4.9	206	.10
1952	509	8.2	42	.02
1953	4,075	5.4	220	.11
Grouse Creek:				
1951	6,801	4.9	333	.16
1952	2,856	1.5	43	.02
1953	2,258	4.7	106	.05
Clear Creek:				
1953	6,658	9.4	626	.32
All Streams:				
1949	21,743	2.4–11.6	1,560	.78
1950	12,647	4.9–11.6	1,105	.55
1951	16,692	4.9–12.6	1,359	.65
1952	11,045	1.5–13.8	981	.40
1953	24,101	4.7–15.0	2,471	1.26

Stream fishing—Information on stream fishing in tributaries of Yellowstone Lake is available from only one stream, Pelican Creek. Pelican Creek is open to fishing after July 15, as is the case with the other tributaries. This date has been chosen to allow the completion of most spawning activities. Pelican Creek retains a number of postspawners in the stream each summer due to the large size of the watershed, the size of the stream, and the abundance of food. They are subjected to a relatively small amount of stream fishing, as indicated by the number of tags returned from stream anglers. These returns ranged from 0.6 to 1.8 percent of the total number of prespawners tagged. If these returns actually indicate the number of fish that were retained in Pelican Creek, an average of 139 postspawners remained in the stream with 80 in 1953 and 216 in 1949, representing the extremes. The information gained from stream surveys in 1953 and 1954 revealed that these estimates are reasonable.

Spawning runs and opening date of fishery.—An important relation exists between the times of the spawning runs, the location of the tributaries which the spawners ascend, and the opening date of the fishery. An understanding of the sequence of events for the tributary streams of Yellowstone Lake is necessary to good management of the sport fishery.

Adult fish, as they approach the tributary in which they will spawn, become concentrated in limited areas, and become more vulnerable to fishermen if fishing is in progress during the time that the prespawners are assembling. Adequate escapement of prespawners is essential to maintain population numbers. The manipulation of the opening date of the fishery can help to ensure this escapement.

The heaviest fishing pressure at Yellowstone Lake is directed against the northern shoreline areas. Any change in the opening date of the fishery, as was introduced in 1953, would be expected to produce an effect upon the size of the runs into Arnica and Pelican Creeks and the Fishing Bridge area. On the other

TABLE 29.—*Relation of times of spawning runs into trapped streams to the opening of the lake fishery, 1950 to 1953*

[Fishery opened on May 30 through 1952 and on June 15 in 1953]

Stream and year	Spawning runs begin—	Duration of run in days	Fish counted through traps				Total spawning run
			To opening of lake fishery		After opening of lake fishery		
			Number	Percent	Number	Percent	
Arnica Creek:							
1950	May 20	71	854	22	3,027	78	3,881
1951	May 8	87	1,599	34	3,156	66	4,755
1952	May 18	73	1,182	34	2,341	66	3,523
1953	May 5	80	2,882	64	1,642	36	4,524
Pelican Creek:							
1950	May 20	68	79	1	14,997	99	15,076
1951	May 30	26	905	10	8,518	90	9,423
1952	May 30	30	800	12	5,721	88	6,521
1953	May 12	58	5,805	47	6,638	53	12,443
Chipmunk Creek:							
1950	June 9	59	0	0	12,255	100	12,255
1951	May 30	60					12,585
1952	May 20	57	6,660	67	3,329	33	9,989
1953	May 31	52	7,836	61	3,077	39	7,836
Grouse Creek:							
1951	June 3	56	0	0	12,188	100	12,188
1952	May 26	58	1,852	27	5,097	73	6,949
1953	June 6	46	655	9	6,896	91	7,551

hand, trout approaching Chipmunk and Grouse Creeks which are isolated from the intense fishery to the north, should be little affected by this change. Data are available that demonstrate that the 1953 postponement of the opening date of the lake fishery produced changes as anticipated (table 29).

Arnica Creek, in which the run extends from early May to late July, had from 22 to 34 percent of the total count checked through the upstream trap by the onset of fishing in 1950 to 1952. When the opening was changed from May 30 to June 15 in 1953, more than 60 percent of the total run entered the stream before fishing began. Pelican Creek, also a relatively early run stream, but one of shorter duration, experienced an even more striking effect than at Arnica Creek. No more than 12 percent of the total spawning run had been tabulated by May 30 from 1950 through 1952. With the change of regulation in 1953, 47 percent of the fish were counted by June 15. Data from Grouse and Chipmunk Creeks show a smaller change when the opening date of fishing was advanced because the runs occur at a late date. The isolation of the South Arm from heavy boat or shoreline fishing permits only an insignificant harvest of prespawners moving toward Grouse and Chipmunk Creeks. This relation would apply to all streams in the southern area.

The manipulation of opening dates of the fishery in order to guarantee adequate escapement of spawners into streams can be an important management technique when all pertinent factors are known. The proportion of the early season catch that is composed of fish destined to spawn that year, and the determination of the effects on fishing on immature trout in relation to the effects of fishing on prespawners, should be known before precise predictions can be made on the effects of manipulating opening dates.

Natural mortality of postspawners in the lake

Natural mortality in the lake (lm) and survival (S') may now be estimated, since methods for determining stream and fishing mortality have been considered. After the stream sojourn, some tagged fish are taken by the fishermen, and those remaining in the lake are unaccounted for until the following year. At that time, some appear in the spawning runs as consecutive spawners or enter the fishery

as second-year tag returns. Because so very few spawn a second time, the second-year tag returns provide an estimate of the abundance of surviving postspawners.

First, assume that tag loss during the year after tagging is negligible, as suggested by observations at Arnica Creek. Second, assume that a similar time and space relation exists between the return of first- and second-year tags. This has been shown to be true for all tagging locations except Grouse and Chipmunk Creeks. Then, the fishing mortality estimate for the group of first-year tagged fish is directly applicable to the return of second-year tags. The number of spawners available as second-year tagged fish may be computed in the following fashion, where (1) denotes tags-of-the-year and (2) second-year tags:

$$\frac{Tf_1}{N(Td_1)}=\frac{Tf_2}{NT_2}$$

solving for NT_2,

$$NT_2=\frac{Tf_2 N(Td_1)}{Tf_1}$$

Second-year tagged fish from Grouse and Chipmunk Creeks were more available to the fishery than first-year tagged fish. This was the only instance where second-year postspawners were subjected to greater fishing pressure than first-year fish. Consequently, groups tagged the year before should incur a higher fishing mortality for the season than fish tagged the same season. Spatial characteristics of their second-year tag returns closely resemble those of the first-year Arnica Creek recoveries; both groups were taken commonly in the West Thumb area. Yet, the typical Chipmunk-Grouse pattern of being caught in the South Arm is retained; thus, the availability of these second-year postspawners is determined by using an arbitrary fishing mortality. The value was set at a mean figure between the estimates for the first-year tag returns of Arnica Creek (upper limit) and Chipmunk and Grouse Creeks (lower limit).

Mortality by postspawners in the lake which may be attributable to natural causes for a period of one year (initial availability to the fishery through the following fishing season), and survival may be computed as follows:

$N(Td)-(Tf)=$ Tags unaccounted for at end of first fishing season (Ts),

and

$$(lm)=(Ts)-NT_2;$$

thus,

$$S'=(Ts)-(lm)$$

A summary of mortality and survival data for all years and all tagging locations is provided in table 30. The information is averaged for each year and for each location. Under normal conditions, a typical spawning run can expect a stream mortality of 48.1 percent. Of those surviving from streams, 8.2 percent will be caught by fishermen. More than half (63.1 percent) of those unaccounted for after fishing is completed will fail to survive through the next summer, with the overwinter period being the critical period. Very few fish spawn a second time. The role that mortality and alternate-consecutive spawning play during and after temporary stream residence may be demonstrated by application of these average mortalities to a spawning run of 1,000 fish (table 18). It is shown that under normal circumstances only 10 fish will function as consecutive spawners, while the potential alternate spawners number 42. By these calculations, the number of fish spawning a second time would not exceed 5.2 percent of the original number.

Noteworthy are the fluctuations in mortality estimates from the average for all areas. Estimates of spawning mortality ranged from 94.9 percent (Chipmunk Creek, 1952) to 21.0 percent (Pelican Creek, 1952). Fishing mortality varied considerably less. Maximum fluctuations from the mean of 8.2 percent for stream locations did not exceed 7 percent.

TABLE 30.—*Summary of mortalities and survivals expressed as percentage values*

[Figures in parentheses are stream averages for 1951–53]

Stream	Tag population					
	1949	1950	1951	1952	1953	Average
Arnica Creek:						
Stream:						
Spawning mortality	------	38.0	41.2	35.3	50.3	41.2
Survival	------	62.0	58.8	64.7	49.7	58.8
Lake:						
Fishing mortality	------	8.4	12.6	7.3	9.0	9.3
Natural mortality	------	66.6	61.1	87.4	67.2	70.5
Survival	------	25.0	26.3	5.3	23.8	20.2
Pelican Creek:						
Stream:						
Spawning mortality	65.2	60.8	29.2	21.0	30.5	41.3
Survival	34.8	39.2	70.8	79.0	69.5	58.7
Lake:						
Fishing mortality	11.8	11.8	9.3	13.8	15.0	12.2
Natural mortality	35.1	67.8	64.9	72.0	58.6	59.7
Survival	53.3	20.6	25.8	14.2	26.4	28.2
Chipmunk Creek:						
Stream:						
Spawning mortality	23.0	65.7	------	94.9	48.0	57.9
Survival	77.0	34.3	------	5.1	52.0	42.1
Lake:						
Fishing mortality	2.4	4.9	------	8.2	5.4	5.2
Natural mortality	34.2	45.4	------	74.7	58.9	53.3
Survival	63.4	49.7	------	17.1	35.7	41.5
Grouse Creek:						
Stream:						
Spawning mortality	------	------	44.2	58.9	70.1	57.7
Survival	------	------	55.8	41.1	29.9	42.3
Lake:						
Fishing mortality	------	------	4.9	1.5	4.7	3.7
Natural mortality	------	------	59.2	88.1	86.4	77.9
Survival	------	------	35.8	10.4	9.0	18.4
Clear Creek						
Stream:						
Spawning mortality	------	------	------	------	41.2	41.2
Survival	------	------	------	------	58.8	58.8
Lake:						
Fishing mortality	------	------	------	------	9.4	9.4
Natural mortality	------	------	------	------	46.2	46.2
Survival	------	------	------	------	44.4	44.4
Trap net:						
Lake:						
Fishing mortality	------	------	------	19.5	28.0	23.8
Natural mortality	------	------	------	63.2	53.8	58.5
Survival	------	------	------	17.3	18.2	17.8
Yellowstone River Cascades:						
River:						
Fishing mortality	------	------	25.1	20.0	23.2	22.8
Natural mortality	------	------	43.6	51.0	65.2	53.3
Survival	------	------	31.3	29.0	11.6	24.0
Average for year:						
Stream						
Spawning mortality	44.1	54.8	38.2	52.5	48.0	48.1
Survival	55.9	45.2	61.8	47.5	52.0	51.9
Lake and River combined:						
Fishing mortality	7.0	8.3	13.0	11.7	13.5	11.6
	------	------	(8.9)	(7.7)	(8.7)	(8.2)
Natural mortality	34.7	59.8	57.2	72.7	62.3	61.4
	------	------	(61.7)	(80.6)	(63.4)	(63.1)
Survival	58.4	31.8	29.8	15.6	24.2	27.0
	------	------	(29.3)	(11.8)	(27.9)	(28.6)

Estimates of fishing mortality for the trap net and Cascades tagging ranged from 19.5 percent to 28.0 percent, and the mean was 23.2 percent. The maximum and minimum estimates for natural mortality in the lake were 88.1 percent and 34.2 percent. This fluctuation did not exceed 28 percent of the mean estimate of 61.4 percent.

The principal factors influencing mortality in lakes are similar to those discussed earlier for streams. Other factors include age, sex, general physical condition, and the degree of parasitism for each fish. The sex of cutthroat trout was shown to be related to the relative amount of weight lost and the length of time spent in the stream. By losing a small amount of body weight exclusive of sex products and by spending a small amount of time in the stream, the adult female should emerge from spawning in better physical condition than the male. This situation was probably the cause of the differential sex mortality at Arnica Creek in 1953. Theoretically, then, the female would be in better condition for overwinter survival. Adults surviving spawning in best condition, or those having the longest and most productive feeding period after returning to the lake may not only experience a higher survival rate, but also represent the best source of consecutive spawners. With regard to age and mortality, 4-year-old fish spawning for the first time would spend a year longer in the lake as feeders than 3-year-old initial spawners. Consequently, they might be in better physical condition before and after spawning. These factors may interact in a complex fashion, providing a basis for differential survival rates, alternate-consecutive spawning ratios, and a relatively high rate of natural lake mortality.

Dispersal of postspawners.—Apparent migration of adult fish from the various tagging locations was indicated by the distribution of tags returned from the sport fishery. For purposes of analysis, five areas were delimited in the Methods

section either by geographic or fishery characteristics, or both (fig. 2).

In terms of fishing pressure, the Fishing Bridge area represents the focal point of the most concentrated fishing effort on the lake (Cope, 1957). If fishing here may be considered "very heavy," then by comparison fishing effort in the northern area could be termed "heavy." The fishery in West Thumb might be classified as "moderate," while the southern area supports "light" fishing pressure. Angling on the Yellowstone River most closely approximates that of the northern area and therefore may be called "heavy."

Tagged fish taken by fishermen were tabulated into first- and second-year returns by stream group and for individual years, and apportioned into areas where captured (appendix table 12). In some cases, the total return of tags for the year (table 21) may be greater than that used in the analysis of tag return areas, because tags are sometimes returned from the fishery without information concerning the date and place of capture. For this reason, questionable tags were eliminated from consideration at this time. Therefore, this presentation depicts the average relative contribution of tagged fish from various streams to designated areas.

Tag return areas for postspawners.— Arnica Creek fish were taken mostly in the West Thumb area. The lake section adjacent to the mouth of Arnica Creek accounted for the greatest number of first- and second-year tagged fish. Pumice Point and the dock area in West Thumb proper, Rock Point and Bridge Bay in the northern half, and the southern part of the Fishing Bridge area were other focal points for the return of Arnica Creek tags.

Second-year tags entered the western shoreline of the northern area to a greater extent than did first-year tags. For purposes of computing lake mortality and survival, however, the movement could not account for second-year tagged fish being exposed to a markedly different fishing pressure.

The northern area accounted for an average of about 65 percent of first- and second-year tags from Pelican Creek. The greatest number from any one location came from the heavily fished southern portion of the Fishing Bridge area. Only an occasional Pelican Creek fish was detected in the Yellowstone River proper. The most productive localities for the return of Pelican Creek tags were Steamboat Point, Bridge Bay, and Mary Bay, all on the north shore of Yellowstone Lake. A slight spatial dispersion of second-year tags was detected, but not to the extent of introducing these postspawners to a radically different fishing pressure.

Results of tagging at Clear Creek suggest a generalized migration into the northern area. Rock Point, Bridge Bay, Stevenson Island, the southern part of the Fishing Bridge area, and the shoreline adjacent to Clear Creek itself were important localities for tag returns. More marked fish from this stream were caught in Bridge Bay than in any other locality. No indication of a movement of Clear Creek fish into the Yellowstone River was detected.

Tag recoveries of Grouse and Chipmunk Creek fish demonstrated the southern half and West Thumb areas to be the most important parts of the lake with regard to capture and apparent migration. Large boats in the South Arm landed the majority of tagged fish from these two tributaries. Occasionally marked fish were were taken in the Southeast Arm, at Bridge Bay, Dot Island, Wolf Point, and in the vicinity of the West Thumb dock. Because second-year tags dispersed into the West Thumb area to a greater extent than did tags of the year, modification in the method of estimation of natural mortality in the lake was necessary.

Considering the unequal distribution of fishing effort on Yellowstone Lake, these data support a view that postspawners from various streams tend to localize in lake areas nearest the parent stream itself, regardless of time. No evidence is at

hand to indicate any appreciable movement of "lake" fish into the Yellowstone River below Fishing Bridge. Both first- and second-year tags typically are caught in the same general areas of the lake, with some exception of adult fish from Chipmunk and Grouse Creeks.

Tagged fish from the trap net and Cascades operations have also been considered in relation to locality of capture (table 31). The Fishing Bridge and Yellowstone River areas were the ones primarily involved in the analysis. Because of the small number of returns from the three lake areas, they were combined and designated the Yellowstone Lake area. These data led to a good understanding of the movements of "river" and "lake" fish.

About half of all Cascades tags recovered were taken in the Fishing Bridge area, and were distributed rather uniformly throughout the area. Second-year tagged fish appeared in the lake fishery in larger relative numbers than did first-year tags. An average of 10.2 percent of the returns from first-year tags were taken in Yellowstone Lake proper, while 27.8 percent of the second-year tags were caught in the lake. An average of 7.1 percent of the trap net fish recovered the first year were caught in the river; as second-year tags, one-fourth of those captured came from the river. More trap net fish were taken in the Fishing Bridge area than in all other areas combined. This operation furnished additional proof that relatively little movement of lake fish into the river system took place. Second-year tags dispersed more than did first-year tags.

Time intervals between tagging and capture.—Apparently the movement of trap-net fish back into the lake from the Fishing Bridge area made them much less available to capture thereafter than were the Cascades fish moving downriver. That is, "river" fish, having moved back into the river after spawning near Fishing Bridge, were still confined to a relatively limited area and largely exposed to the full extent of the fishing pressure developed there. Trap-net fish, on the other hand, retreated into an extensive lake area that was fished mostly along certain portions of the shoreline. A comparison of the fishing success from both groups provides additional evidence that the migration characteristics probably determined postspawner availability.

The effect of postspawner dispersion from Arnica Creek, the trap net, and the Cascades is further demonstrated by measuring the time between availability of tagged fish to the fishery and their capture (table 32). The usable tag returns from Arnica Creek from 1950 to 1952 were combined in order to obtain a sufficient number of returns for this purpose. The length of time from the moment of availability to the fishery to date of capture for each fish was arranged into weekly intervals. The initial moment of availability began with the opening date of the lake fishery if the

TABLE 31.—*Fishery returns by areas from Cascades and trap net tagging*

Location and year of tagging	Percentage of total returns from—						Total number of returns	
	Yellowstone Lake area		Fishing Bridge area		Yellowstone River area			
	1st-year	2d-year	1st-year	2d-year	1st-year	2d-year	1st-year	2d-year
Cascades:								
1951	10.5	38.1	38.4	42.9	51.2	19.0	86	21
1952	14.9	20.8	52.2	54.2	32.8	25.0	67	24
1953	5.6	22.2	61.1	33.3	33.3	44.5	72	9
Three years	10.2	27.8	49.8	46.3	40.0	25.9	225	54
Trap net:								
1952	23.7	10.0	69.5	60.0	6.8	30.0	59	20
1953	10.4	18.2	82.1	63.6	7.5	18.2	67	11
Two years	16.7	12.9	76.2	61.3	7.1	25.8	126	31

TABLE 32.—*Summary of time intervals before capture expressed in weekly increments from the moment of availability to the fishery*

Time of capture by weekly periods	Percent of total tagged in—									
	Arnica Creek			Cascades				Trap net		
	1950–52	1953	All years	1951	1952	1953	All years	1952	1953	All years
May 4–10	6.7	17.4	13.1	49.4	13.0	43.8	35.6	52.3	47.1	49.6
May 11–17	17.8	11.6	14.0	15.9	15.9	21.9	18.0	25.4	33.8	29.8
May 18–24	15.5	16.0	15.8	18.9	14.5	15.1	16.1	15.9	11.8	13.7
May 25–31	11.1	5.8	7.9	11.6	26.1	5.6	14.2	4.8	4.4	4.6
June 1–7	6.7	4.3	5.3	1.4	11.6	5.6	6.2	------	2.9	1.5
June 8–14	11.1	16.0	14.0	1.4	5.8	4.1	3.8	1.6	------	.8
June 15–21	11.1	13.0	12.3	1.4	5.8	1.3	2.8	------	------	------
June 22–28	11.1	11.6	11.4	------	4.4	1.3	1.9	------	------	------
June 29–July 5	6.7	4.3	5.3	------	2.9	1.3	1.4	------	------	------
July 6–12	2.2	------	.9	------	------	------	------	------	------	------
Total number of tags	45	69	114	69	69	73	211	63	68	131

fish had been liberated into the lake or river prior to that date. If liberation into the lake took place after fishing had begun, then the date of liberation became the moment of availability.

About half of the recovered trap-net fish were caught within the first week following availability. As a rule, less than 7 percent were caught after the third week of exposure to the fishery. This pattern also generally applied to fish from the Cascades, where most of the marked fish were recovered within a week or two after becoming available. However, Cascades fish were caught over a longer period of time than were the trap-net fish for reasons previously suggested. This condition emphasizes the role of dispersion as it determines the rate of tag return. For instance, an average of about 30 percent of the Cascades fish landed from 1951 to 1953 were taken after the third week of availability, while only 6.9 percent of the trap-net fish normally entered the creel after 3 weeks' exposure to the fishermen. The deviation of the results of Cascades tagging in 1952 from the 1951 and 1953 data probably resulted from the effects of the earlier spawning migration in 1952. An earlier movement of mature fish may have allowed a greater number, possibly the bulk of the run, to appear in the Fishing Bridge area and disperse in the river before the period of most intense fishing. An extension of the length of time between availability and capture would result, as indicated by the data.

The evidence at hand shows that the fishery in and around the Fishing Bridge area is dependent on the influx of mature fish from the river and lake. The opening date of the river fishery, July 1, occurs during the period of spawning migration into this area. The movement up the river seems to precede that from the lake by a week or two. On July 1, heavy fishing pressure is imposed upon the limited area where the accumulation of fish has been taking place. Measurements of fishing intensity and the creel census estimates have demonstrated the great success of the Fishing Bridge area anglers during the first few weeks of July (Moore, Cope, and Beckwith, 1952). The angling success appears to be related to the movement of fish into the area (table 33). The data suggest that in 1952 early spawning runs by "river" and "lake" fish allowed a considerable escapement from the area by postspawners

TABLE 33.—*Relation between the Fishing Bridge catch and the trap-net and Cascades fishing-intensity estimates*

Year	Total catch (fish)	Peak rate of fishing (percent)		Fishing mortality (percent)	
	Fishing Bridge	Trap net	Cascades	Trap net	Cascades
1950	6,417	----------	----------	----------	----------
1951	8,938	----------	10.6	----------	22.3
1952	4,865	7.9	5.7	17.5	17.8
1953	5,388	14.1	8.6	24.7	20.6

back into their respective areas of origin before fishing began. This condition is generally reflected in the Fishing Bridge catch and the fishing intensity measurements, although other factors interact here to obscure the association between fishing mortality rates and Fishing Bridge catches.

The estimates of natural lake mortality for Cascades and trap-net fish, including the effects of spawning, compare favorably with the natural mortality (*lm*) estimates from streams. The sources of spawning mortality which operate in streams are much less emphasized around the river outlet. Furthermore, many adults that otherwise would have succumbed to spawning are prematurely taken by the Fishing Bridge area fishermen.

Second-year river and lake tags appeared in the Fishing Bridge area fishery in greater relative proportion than did the first-year tags. This appears to refute the alternate-consecutive spawning concept and the theory that the Fishing Bridge fishery is almost completely dependent on the movements of initial spawners. Dispersion of second-year tagged fish has been demonstrated. This may be due to a migration of postspawners toward feeding areas in the lake near the outlet. Moreover, a higher percentage of consecutive spawners may dominate these two groups, in which a greater movement to the Fishing Bridge area as second-year tags would result. A more uniform and favorable aquatic environment in the river could result in postspawners being in better physical condition and lead to a greater tendency for consecutive spawning.

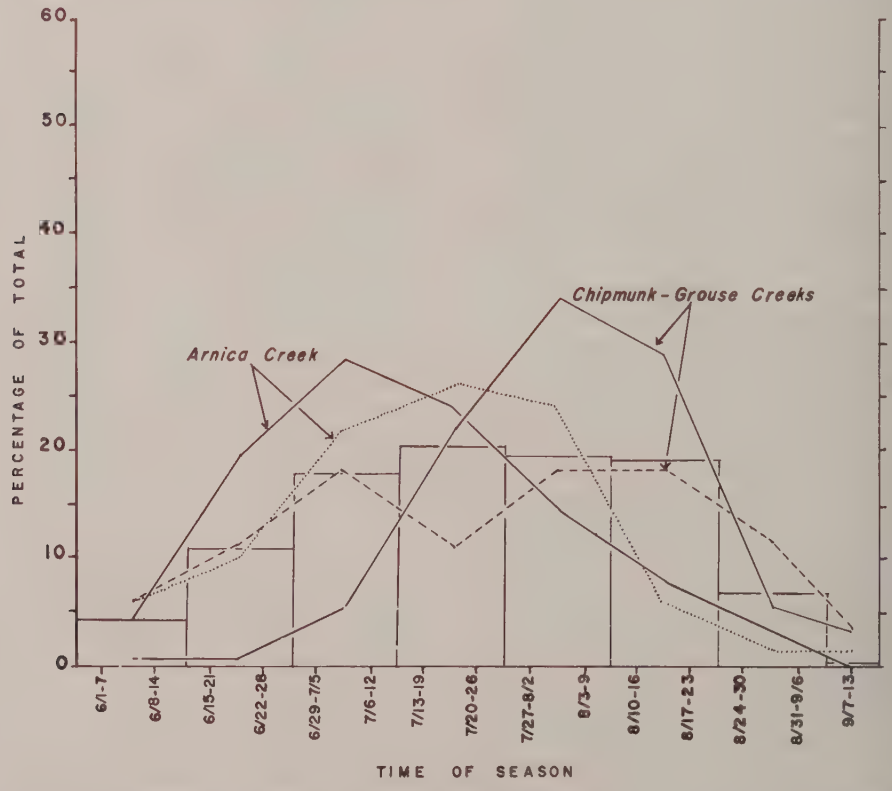

FIGURE 6.—Arnica and Grouse and Chipmunk Creeks average annual returns, compared with the West Thumb area fishery catch, 1950 to 1953. Histogram represents average annual catch, solid lines are first-year returns, and broken lines are second-year returns.

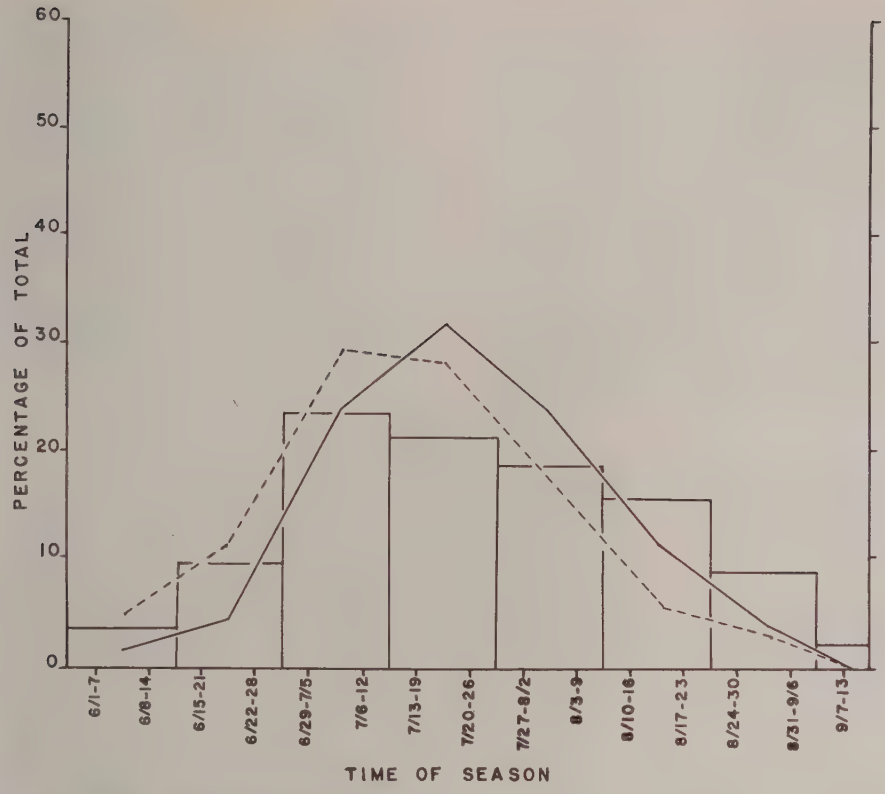

FIGURE 7.—Pelican Creek average annual returns of tagged fish, compared with the distribution of the Fishing Bridge area fishery catch, 1949 to 1953. Histogram represents average annual catch, solid lines are first-year returns, and broken lines are second-year returns.

West Thumb fishery.—Tagged fish from Arnica and Chipmunk-Grouse Creeks were characteristically taken in the West Thumb area. First year postspawners from the South Arm usually entered the fishery late in the season. As second-year tags, they were more uniformly harvested throughout the season. Postspawners from Arnica Creek followed a similar pattern both as first- and as second-year tags. Period returns showed them to be taken much earlier in the season than were Chipmunk and Grouse Creek fish (fig.6, appendix table 7).

The West Thumb fishery is unusual in that a successful catch is extended over a longer period of time than any of the other components of the Yellowstone fishery (table 5). The tag returns from Arnica Creek and Chipmunk and Grouse Creeks help explain this situation. The endemic population resulting from reproduction within the boundaries of West Thumb is a small one. The presence of so few spawning tributaries in that area, Arnica Creek being one of the two largest, substantiates this conclusion. Therefore, the highly successful early-season fishery of the northern portion of the lake and in the Yellowstone River, which appears to be largely dependent on prespawning movement of adult fish, is lacking in West Thumb (fig. 7). The fishery of the Fishing Bridge area takes postspawners from Pelican Creek fairly early in the season, compared with the entry of Chipmunk and Grouse Creek postspawners into the West Thumb fishery. The West Thumb fishery must be rather dependent on a recruitment or migration of fish from other

areas later in the season. This is suggested by the period returns of Grouse-Chipmunk and Arnica Creeks when compared with the creel census from the West Thumb area, where most of the tags are returned. The early fishery is supported by adult fish before and after spawning. The dispersion of postspawners later in the season, as indicated by the Arnica Creek period returns, would normally lead to a decrease in catch at that time, as was demonstrated elsewhere. However, postspawners from Grouse and Chipmunk Creeks are shown to re-enter the lake during the latter part of July, and appear in the West Thumb fishery several weeks later. Hence, the late season movement of fish into West Thumb probably stems from postspawners immature fish, and recruitment of small adults. Not only do they move in from the South Arm and Southeast Arm, but also from other portions of the southern section of Yellowstone Lake. Nevertheless, this recruitment, as suggested by tag returns, at best extends a limited fishery into one of moderate proportions.

SUMMARY

The Fish and Wildlife Service studied factors associated with mortality of eggs, immature fish, spawners, and postspawners of the Yellowstone cutthroat trout in Yellowstone Lake (Wyoming) and its tributaries. These efforts were connected with broad studies intended to determine the number of trout that can be removed from these waters without damaging the populations.

Background material is furnished to describe the biology of the cutthroat and its physical and biological environment in the lake and streams. Water temperatures, history of trout management, sizes of the spawning runs, sex ratios in favor of the females in spawning runs, and the characteristics of the extensive and intensive sport fishery are discussed.

Methods of measuring mortality of eggs and fry by examination of redds, mortality of fry, fingerlings, and adults by counting through upstream-downstream traps, and mortality of adults by tagging with Petersen disks and recovery at traps and in the fishery, are described. Five methods of computation are given to show ways of determining mortality of adults in streams by trap counts and by recovery of tags from the fishery.

Deaths of cutthroat eggs in the gravel in Arnica Creek ranged from 60 to 75 percent to the time of hatching, 36 to 40 days after deposition. Deaths to the time the swimming fry and fingerlings left Arnica Creek and entered Yellowstone Lake averaged 99.6 percent of the original eggs deposited in the stream. Thus, for every female spawner with an average of 1,107 eggs, 4.54 immature trout were alive in September of the first year. Of these, 1.67 must survive to become spawners in order to maintain the population in numerical stability over a period of time.

Efficiency of return of tags recovered from fishermen was determined to be 88.6 percent. Tagged adults in Arnica Creek were found to have a maximum of 12 percent higher death rate in the stream than did fish not tagged. Male and female trout were observed to suffer essentially the same mortalities. The average mortality of spawners in 5 streams during 5 years was 48.1 percent. The upstream-downstream tagging method, devised for these studies for measurement of upstream mortality, was tested against upstream-downstream counts in Arnica Creek and found to give accurate estimates. No explanation is found to explain the uneven sex ratio in the spawning runs (1.47 females to 1 male) or in the fishery (1.62 females to 1 male). Males stayed upstream in Arnica Creek for an average of 17.3 days; females averaged 7.3 days. Evidently, many male spawners service more than one female. Males lose an average of 18.5 percent of their body

weight while on the spawning run; females lose 21.3 percent. The peaks of spawning runs occurred when water temperatures reached the vicinity of 55° F. The early portion of the spawning run had relatively high mortality, the peak of the run suffered fewer deaths, and the last part, during periods of increasing water temperatures, sustained heavy losses. Spawners spent less time in the stream as the season progressed. Fish that were artificially spawned and returned to upstream water had lower mortality rates than fish that spawned naturally in Chipmunk Creek, but had higher rates in Pelican Creek. Of trout that returned to spawn a second time, an average of 6.9 percent of those alive spawned consecutively (the next year), while 22.8 percent of those alive spawned alternately (2 years later). Relatively few fish spawned a second time; 1.22 percent of the runs were fish that had spawned before.

Of the fish in Arnica Creek spawning runs, 48.6 percent died in the stream, 40.2 percent died later in the lake of natural causes, 7.6 percent were caught by fishermen, and 3.6 percent were alive 2 years later.

The white pelicans that breed on the Molly Islands in the Southeast Arm of Yellowstone Lake consume from 300,000 to 450,000 pounds of fish each year. Most of these fish are cutthroat trout from Yellowstone Lake. The fish are caught principally in the south end of the lake, near the mouths of streams and on the spawning beds. Other predators take lesser tolls, the osprey and the bear being two most serious rivals to the pelican.

Postspawners from five streams contributed less than 2 percent of the fishery. Tag returns from postspawners showed that fishing mortality among fish released from a trap net in the lake and on fish tagged at the Cascades on the Yellowstone River was several times greater than mortalities estimated for postspawners from smaller streams. Fish were released directly into areas with heavy fishing at the former locations; fish were able to disperse into the lake from tributary streams, and longer times before capture were characteristic of the stream populations. Average fishing mortality in fish tagged in the lake and river from 1949 to 1953 was 11.6 percent of the fish available to the fishermen.

Tagging showed that many trout move upstream to the Fishing Bridge area to spawn and return downriver after spawning; also, many move from the lake to the Fishing Bridge area to spawn and reenter the lake after spawning. There was little passage of "river" fish into the lake or "lake" fish into the river. Tagging also indicated that many postspawners from Chipmunk and Grouse Creeks move into West Thumb before entering the fishery. This migration pattern suggests a reason for the late season fishery in the West Thumb area. The heaviest harvest of fish takes place in the northern part of the lake.

Changing the opening date of fishing from May 30 to June 15 in 1953 resulted in considerable escapement of spawners into streams.

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APPENDIX TABLES

APPENDIX TABLE 1.—*Fishing intensity data obtained from upstream tagging at Arnica Creek, 1950–52*

Time period	Tag group checked downstream			Tagged fish checked downstream by periods				Rates of fishing
	Tag group	Fishing returns	Fishing mortality	Time group	Period fishing returns		Cumulative availability	
1950	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Percent*
May 4–10								
May 11–17								
May 18–24	12	4	33					
May 25–31	47	3	6					
June 1–7 [1]	176	10	6					
June 8–14	218	9	4					
June 15–21	41	4	10	312	0	0	312	0.0
June 22–28	41	8	20	79	2	5	391	.5
June 29–July 5	12	2	17	112	12	27	501	2.4
July 6–12	10	2	20	13	7	16	502	1.4
July 13–19	12	2	17	8	6	14	503	1.2
July 20–26	29	0	0	4	5	11	501	1.0
July 27–Aug. 2				29	3	7	525	.6
Aug. 3–9				8	3	7	530	.6
Aug. 10–16				25	3	7	552	.5
Aug. 17–23				4	1	2	553	.2
Aug. 24–30				4	1	2	556	.2
Aug. 31–Sept. 6					1	2	555	.2
Sept. 7–13							554	.0
Total	598	44	7.4	598	44	7.4	554	
1951								
May 4–10	3	0	0					
May 11–17	53	12	23					
May 18–24	79	10	13					
May 25–31	206	27	13	3				
June 1–7	135	8	6	135			138	.0
June 8–14	71	7	10	243	5	6	381	1.3
June 15–21	34	5	15	135	8	10	511	1.6
June 22–28	45	7	16	70	12	15	573	2.1
June 29–July 5	37	3	8	31	10	12	592	1.7
July 6–12	28	2	7	37	7	9	619	1.1
July 13–19	20	1	5	42	12	15	654	1.8
July 20–26	11	0	0	11	11	13	653	1.7
July 27–Aug. 2	8	0	0	20	2	2	662	.3
Aug. 3–9	6	0	0	6	6	7	666	.9
Aug. 10–16				3	4	5	663	.6
Aug. 17–23					2	2	659	.3
Aug. 24–30					2	2	657	.3
Aug. 31–Sept. 6					1	1	655	.2
Sept. 7–13							654	.0
Total	736	82	11.1	736	82	11.1	654	
1952								
May 5–10								
May 11–17								
May 18–24	62	7	11	29				
May 25–31	131	13	10	78				
June 1–7	210	12	6	99	0		206	.0
June 8–14	125	5	4	67	5	13	273	1.8
June 15–21	47	1	2	110	6	15	378	1.6
June 22–28	13	0	0	142	5	13	514	1.0
June 29–July 5	8	0	0	21	7	18	530	1.3
July 6–12	9	1	11	40	8	20	563	1.4
July 13–19	6	1	17	5	2	5	560	.4
July 20–26	5	0	0	11	2	5	569	.4
July 27–Aug. 2	4	0	0	13	1	2	580	.2
Aug. 3–9				5	0		584	.0
Aug. 10–16				0	3	8	584	.5
Aug. 17–23				0	1	2	581	.2
Aug. 24–30				0			580	.0
Aug. 31–Sept. 6							580	.0
Sept. 7–13							580	.0
Total	620	40	6.5	620	40	6.5	620	

[1] Fishing began on May 30.

APPENDIX TABLE 2.—*Fishing intensity data obtained from tagging at Arnica Creek, 1953*

SECTION 1—UPSTREAM TAGGING

Time period	Tag group checked downstream			Tagged fish checked downstream by period—time group					Fishing returns (number)	Fishing mortality (percent)
	Tag group (number)	Fishing returns (number)	Fishing mortality (percent)	Time group (number)	Period fishing returns		Cumulative availability	Rates of fishing (percent)		
					Number	Percent				
May 4–10	13	2	15							
May 11–17	37	4	11	7					1	14
May 18–24	35	2	6	5					0	0
May 25–31	98	11	11	29					5	17
June 1–7	105	11	10	49					6	12
June 8–14	77	3	4	96					11	11
June 15–21	51	6	12	104	4	10	290	1.4	10	10
June 22–28[1]	35	1	3	30	2	5	316	.6	1	3
June 29–July 5	33	0	0	60	9	23	374	2.4	5	8
July 6–12	13	0	0	105	4	10	470	.9	1	1
July 13–19	7	0	0	13	4	10	479	.8	0	0
July 20–26	1	0	0	5	5	13	480	1.0	0	0
July 27–Aug. 2				2	5	13	477	1.0	0	0
Aug. 3–9					4	10	472	.8		
Aug. 10–16	1	0	0		2	5	468	.4		
Aug. 17–23				1	1	3	467	.2	0	0
Aug. 24–30							466	.0		
Aug. 31–Sept. 6							466	.0		
Sept. 7–13							466	.0		
Total	506	40	7.9	506	40		466		40	7.9

[1] Fishing began on June 15.

SECTION 2—DOWNSTREAM TAGGING

Time period	Tagged fish checked downstream by period—time group					Time group fishing returns	Time group fishing mortality
	Time group	Period fishing returns		Cumulative availability	Rates of fishing		
	(Number)	Number	Percent	(Number)	(Percent)	(Number)	(Percent)
May 4–10							
May 11–17							
May 18–24	7					0	0
May 25–31	14					2	14
June 1–7	25					3	12
June 8–14	60					5	8
June 15–21	69	5	17	175	2.9	12	17
June 22–28[1]	23	2	7	193	1.0	2	9
June 29–July 5	41			232	.0	4	10
July 6–12	97	3	10	329	.9	1	1
July 13–19	9	4	14	335	1.2	0	0
July 20–26	2	4	14	333	1.2	0	0
July 27–Aug. 2	3	6	20	332	1.8	0	0
Aug. 3–9	1	4	14	327	1.2	0	0
Aug. 10–16				323	.0		
Aug. 17–23		1	3	323	.3		
Aug. 24–30	1			323	.0	0	0
Aug. 31–Sept. 6	1	0		324	.0	0	0
Sept. 7–13				324	.0		
Total	353	29		324		29	8.2

[1] Fishing began on June 15.

APPENDIX TABLE 2.—*Fishing intensity data obtained from tagging at Arnica Creek, 1953*—Continued

SECTION 3—UPSTREAM AND DOWNSTREAM TAGGING

[Combined comparable portions of Sections 1 and 2.]

Time period	Tagged fish checked downstream by period—time group					Time group fishing returns	Time group fishing mortality
	Time group	Period fishing returns		Cumulative availability	Rates of fishing		
	(Number)	Number	Percent	(Number)	(Percent)	(Number)	(Percent)
May 4–10							
May 11–17	7					1	14
May 18–24	12					0	0
May 25–31	43					7	16
June 1–7	74					9	12
June 8–14	156					16	10
June 15–21	173	9	13	465	1.9	22	13
June 22–28 [1]	53	4	6	509	.8	3	6
June 29–July 5	101	9	13	606	1.5	9	9
July 6–12	202	7	10	799	.9	2	1
July 13–19	22	8	12	814	1.0	0	0
July 20–26	7	9	13	813	1.1	0	0
July 27–Aug. 2	5	11	16	809	1.4	0	0
Aug. 3–9	1	8	12	799	1.0	0	0
Aug. 10–16		2	3	791	.3		
Aug. 17–23	1	2	3	790	.3	0	0
Aug. 24–30	1	0		789	.0	0	0
Aug. 31–Sept. 6	1	0		790	.0	0	0
Sept. 7–13	0	0		790	.0		
Total	859	69		790		69	8.0

[1] Fishing began on June 15.

APPENDIX TABLE 3.—*Rates of fishing obtained from downstream tagging at Pelican Creek, 1952*

Time period	Number tagged	Period returns		Cumulative availability (Number)	Rate of fishing (Percent)	Time group fishing mortality	
		Number	Percent			Number	Percent
June 1–7							
June 8–14							
June 15–21	64			64	0.0	7	11
June 22–28				64	0.0		
June 29–July 5	103	1	5	167	0.6	13	13
July 6–12	0	5	25	166	3.0		
July 13–19	0	3	15	161	1.9		
July 20–26	0	5	25	158	3.2		
July 27–Aug. 2	0	2	10	153	1.3		
Aug. 3–9	0	1	5	151	0.7		
Aug. 10–16	0	3	15	150	2.0		
Aug. 17–23	0			147	0.0		
Aug. 24–30	0			147	0.0		
Aug. 31–Sept. 6	0			147	0.0		
Sept. 7–13	0			147	0.0		
Total	167	20	100	147		20	12.0

APPENDIX TABLE 4.—*Rates of fishing obtained from downstream tagging at Chipmunk and Grouse Creeks, 1952 and 1953*

Time period	1952				1953			
	Number tagged (Number)	Period returns (Number)	Cumulative availability (Number)	Rate of fishing (Percent)	Time group (Number)	Period returns (Number)	Cumulative availability (Number)	Rate of fishing (Percent)
June 1–7	[1]							
June 8–14					[1]			
June 15–21	17		17	0.0				
June 22–28	32		49	0.0				
June 29–July 5			49	0.0	64		64	0.0
July 6–12	29	1	78	1.3	30		94	0.0
July 13–19	94		171	0.0	22		116	0.0
July 20–26	68	4	239	1.7	69		185	0.0
July 27–Aug. 2	87	2	322	0.6	99	2	284	0.7
Aug. 3–9		3	320	0.9		5	282	1.8
Aug. 10–16		1	317	0.3		2	277	0.7
Aug. 17–23			316	0.0		2	275	0.7
Aug. 24–30			316	0.0			273	0.0
Aug. 31–Sept. 6			316	0.0		1	273	0.4
Sept. 7–13			316	0.0			272	0.0
Total	327	11	316		284	12	272	

[1] Opening of fishing season.

APPENDIX TABLE 5.—*Period fishing returns obtained from tagging at Pelican Creek, 1949 to 1953*

[Percentage of total returns for each season given in parentheses]

Time period	Number of fish returned from—											
	1949 tagging		1950 tagging		1951 tagging		1952 tagging		1953 tagging		Total tagging	
	1949	1950	1950	1951	1951	1952	1952	1953	1953	1954	First year	Second year
June 1–7		2(14)	1(2)			1(4)					1(0.3)	3(3)
June 8–14	4(15)		1(2)			2(7)	1(1)				6(2)	2(2)
June 15–21			1(2)			2(7)	4(4)	2(14)	1(1)	3(10)	6(2)	7(7)
June 22–28	2(7)		4(7)	1(11)	2(3)		3(3)			4(13)	11(3)	5(5)
June 29–July 5	7(26)	2(14)	4(7)	3(33)	2(3)	5(18)	15(16)	1(7)	9(8)	3(10)	37(10)	14(15)
July 6–12	4(15)		3(6)	3(33)	9(12)	3(11)	17(18)	4(29)	15(13)	4(13)	48(13)	14(15)
July 13–19	2(7)	3(21)	9(17)		9(12)	2(7)	5(5)	2(14)	13(11)	4(13)	38(10)	11(11)
July 20–26	5(19)	1(7)	13(24)		17(23)	8(29)	14(15)	3(21)	29(25)	3(10)	78(21)	15(16)
July 27–Aug. 2	2(7)	3(21)	8(15)	1(11)	10(13)	2(7)	12(13)	1(7)	20(17)	4(13)	52(14)	11(11)
Aug. 3–9	1(4)		7(13)		7(9)	1(4)	8(9)	1(7)	12(10)	3(10)	35(10)	5(5)
Aug. 10–16		1(7)	2(4)	1(11)	6(8)		7(8)		11(9)	2(6)	26(7)	4(4)
Aug. 17–23			1(2)		6(8)	1(4)	2(2)		4(3)	1(3)	13(4)	2(2)
Aug. 24–30		2(14)			7(9)	1(4)	4(4)		2(2)		13(4)	3(3)
Aug. 31–Sept. 6												
Sept. 7–13												
Total	27	14	54	9	75	28	92	14	116	31	364	96

APPENDIX TABLE 6.—*Period fishing returns obtained from the combined Chipmunk Creek and Grouse Creek data, 1949 to 1953*

[Percentage of total returns for each season given in parentheses]

Time period	Number of fish returned from—											
	1949 tagging [1]		1950 tagging [1]		1951 tagging [2]		1952 tagging [3]		1953 tagging [3]		Total tagging	
	1949	1950	1950	1951	1951	1952	1952	1953	1953	1954	First year	Second year
June 1–7				1(8)								1(1)
June 8–14		2(6)		1(8)	1(3)	1(7)					1(1)	4(5)
June 15–21		1(3)		1(8)		3(20)						5(6)
June 22–28		2(6)				1(7)	1(6)			1(10)	1(1)	4(5)
June 29–July 5		3(9)		2(17)		1(7)	1(6)	1(20)	1(4)		2(2)	7(9)
July 6–12	1(9)	2(6)	1(5)	1(8)	1(3)	1(7)	1(6)	1(20)		2(20)	4(4)	7(9)
July 13–19	3(27)	1(3)		2(17)	2(7)	1(7)			2(7)	1(10)	7(7)	5(6)
July 20–26	2(18)	1(3)	1(5)	1(8)	5(17)	1(7)	4(25)	1(20)	3(11)		15(15)	4(5)
July 27–Aug. 2	4(36)	3(9)	3(16)		5(17)	2(13)	4(25)	1(20)	3(11)	1(10)	19(18)	7(9)
Aug. 3–9	1(9)	4(11)	3(16)		3(10)	2(13)	3(19)		6(21)	1(10)	16(16)	7(9)
Aug. 10–16		6(17)	5(26)		4(14)		1(6)		7(25)	3(30)	17(17)	9(12)
Aug. 17–23		2(6)	3(16)	1(8)	6(21)			1(20)	3(11)	1(10)	12(12)	5(6)
Aug. 24–30		5(14)	1(5)			2(13)	1(6)				2(2)	7(9)
Aug. 31–Sept. 6		1(3)	2(11)	1(8)	1(3)				1(4)		4(4)	2(3)
Sept. 7–13		2(6)		1(8)	1(3)				2(7)		3(3)	3(4)
Total	11	35	19	12	29	15	16	5	28	10	103	77

[1] Chipmunk Creek only. [2] Grouse Creek only. [3] Chipmunk and Grouse upstream and downstream tagging combined.

APPENDIX TABLE 7.—*Period fishing returns, all tagging areas, 1949 to 1953*

Time period	Arnica Creek 1950–53				Pelican Creek 1949–53				Chipmunk and Grouse Creeks 1949–53				Yellowstone Cascades 1951–53			
	First-year returns		Second-year returns		First-year returns		Second-year returns		First-year returns		Second-year returns		First-year returns		Second-year returns	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
OPENING OF LAKE FISHERY																
June 1–7					1	0.3	3	3			1	1	3	1		
June 8–14	10	4	3	6	6	2	2	2	1	1	4	5	1	0.4	1	2
June 15–21	23	10	2	4	6	2	7	7			5	6	7	3	3	6
June 22–28	23	10	3	6	11	3	5	5	1	1	4	5	15	6	3	6
OPENING OF RIVER FISHERY																
June 29–July 5	38	16	8	16	37	10	14	15	2	2	7	9	63	26	14	27
July 6–12	29	12	3	6	48	13	14	15	4	4	7	9	55	23	11	22
July 13–19	28	12	3	6	38	10	11	11	7	7	5	6	43	18	8	16
July 20–26	27	11	10	20	78	21	15	16	15	15	4	5	28	12	3	6
July 27–Aug. 2	17	7	7	14	52	14	11	11	19	18	7	9	11	5	3	6
Aug. 3–9	17	7	5	10	35	10	5	5	16	16	7	9	4	2	3	6
Aug. 10–16	12	5	3	6	26	7	4	4	17	17	9	12	3	1		
Aug. 17–23	6	3			13	4	2	2	12	12	5	6	3	1		
Aug. 24–30	3	1	1	2	13	4	3	3	2	2	7	9			2	4
Aug. 31–Sept. 6	2	1							4	4	2	3	1	0.4		
Aug. 7–13			1	2					3	3	3	4	1	0.4		
Total	235		49		364		96		103		77		238		51	

APPENDIX TABLE 7.—*Period fishing returns, all tagging areas, 1949 to 1953*—Continued

Time period	Trap Net 1952–53				Clear Creek 1953				Total for all locations			
	First-year returns		Second-year returns		First-year returns		Second-year returns		First-year returns		Second-year returns	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
OPENING OF LAKE FISHERY												
June 1–7									4	0.4	4	1
June 8–14									18	2	10	3
June 15–21			4	13	1	2			37	3	21	7
June 22–28	8	6	1	3	1	2	2	13	59	5	18	6
OPENING OF RIVER FISHERY												
June 29–July 5	38	29	10	32	1	2	1	7	179	16	54	17
July 6–12	34	26	7	23	4	9			174	16	42	13
July 13–19	29	22	4	13	4	9	3	20	149	13	34	11
July 20–26	10	8	3	10	8	19	4	27	166	15	39	12
July 27–Aug. 2	6	5	1	3	7	16	1	7	112	10	30	9
Aug. 3–9	3	2			10	23	4	27	85	8	24	8
Aug. 10–16	1	1	1	3					59	5	17	5
Aug. 17–23					6	14			40	4	7	2
Aug. 24–30					1	2			19	2	13	4
Aug. 31–Sept. 6									7	1	2	1
Aug. 7–13									4	.4	4	1
Total	129		31		43		15		1,112		319	

APPENDIX TABLE 8.—*Fishing rates and period fishing returns obtained from trap-net tagging, 1952 and 1953*

Time period	1952				1953			
	Period tag returns		Cumulative availability (number)	Rate of fishing (percent)	Period tag returns		Cumulative availability (number)	Rate of fishing (percent)
	Number	Percent			Number	Percent		
OPENING OF LAKE FISHERY								
June 1–7								
June 8–14								
June 15–21							6	0.0
June 22–28	5	8	111	4.5	3	4	103	2.9
OPENING OF RIVER FISHERY								
June 29–July 5	11	18	156	7.1	27	40	192	14.1
July 6–12	17	28	215	7.9	17	25	216	7.9
July 13–19	15	25	284	5.3	14	21	215	6.5
July 20–26	6	10	305	2.0	4	6	211	1.9
July 27–Aug. 2	4	7	299	1.3	2	3	210	1.0
Aug. 3–9	2	3	295	.7	1	1	208	.5
Aug. 10–16	1	1	293	.3			207	.0
Aug. 17–23			292	.0			207	.0
Aug. 24–30			292	.0			207	.0
Aug. 31–Sept. 6			292	.0			207	.0
Sept. 7–13			292	.0			207	.0
Total	61		292		68		207	

APPENDIX TABLE 9.—*Fishing mortalities obtained from trap-net tagging, 1952 and 1953*

[Numbers in parentheses indicate numbers of immature fish]

Time period	1952			1953		
	Tag group (number)	Group returns (number)	Fishing mortality (percent)	Tag group (number)	Group returns (number)	Fishing mortality (percent)
OPENING OF LAKE FISHERY						
June 1–7						
June 8–14						
June 15–21	4(6)	0(0)	0	6	2	33
June 22–28	107(18)	27(0)	25	97	30	31
OPENING OF RIVER FISHERY						
June 29–July 5	50(18)	14(0)	28	92	26	28
July 6–12	70(25)	15(1)	21	51	7	14
July 13–19	86(22)	2(1)	2	16	2	13
July 20–26	36(12)	3(0)	8	10	1	10
July 27–Aug. 2				3		
Aug. 3–9						
Aug. 10–16						
Aug. 17–23						
Aug. 24–30						
Aug. 31–Sept. 6						
Aug. 7–13						
Total	353(101)	61(2)	17.3(2.0)	275	68	24.7

APPENDIX TABLE 10.—*Fishing rates and period fishing returns obtained from tagging at the Cascades of the Yellowstone River, 1951 to 1953*

Time period	1951				1952				1953			
	Period tag returns		Cumulative availability (number)	Rate of fishing (percent)	Period tag returns		Cumulative availability (number)	Rate of fishing (percent)	Period tag returns		Cumulative availability (number)	Rate of fishing (percent)
	Number	Percent			Number	Percent			Number	Percent		
OPENING OF LAKE FISHERY												
June 1–7					3	4	110	2.7				
June 8–14			76	0.0	1	1	223	0.4				
June 15–21	2	2	126	1.6	5	7	318	1.6			77	0.0
June 22–28	2	2	181	1.1	7	10	386	1.8	6	8	176	3.4
OPENING OF RIVER FISHERY												
June 29–July 5	19	21	179	10.6	22	31	384	5.7	22	28	256	8.6
July 6–12	22	25	332	6.6	15	21	362	4.1	18	23	343	5.2
July 13–19	25	28	354	7.1	4	6	347	1.2	14	18	331	4.2
July 20–26	11	13	329	3.3	7	10	343	2.0	10	13	319	3.1
July 27–Aug. 2	6	7	318	1.9	2	3	336	0.6	3	4	309	1.0
Aug. 3–9	1	1	312	0.3	1	1	334	0.3	2	3	306	0.7
Aug. 10–16	1	1	311	0.3	1	1	333	0.3	1	1	304	0.3
Aug. 17–23			310	0.0	1	1	332	0.3	2	3	303	0.7
Aug. 24–30			310	0.0			331	0.0			301	0.0
Aug. 31–Sept. 6			310	0.0	1	1	331	0.3			301	0.0
Sept. 7–13			310	0.0	1	1	330	0.3			301	0.0
Total	89		310		71		329		78		301	

APPENDIX TABLE 11.—*Fishing mortalities obtained from tagging at the Cascades of Yellowstone River, 1951 to 1953*

Time period	1951			1952			1953		
	Tag group (Number)	Group returns (Number)	Fishing mortality (Percent)	Tag group (Number)	Group returns (Number)	Fishing mortality (Percent)	Tag group (Number)	Group returns (Number)	Fishing mortality (Percent)
May 25–31				38	7	18			
OPENING OF LAKE FISHERY									
June 1–7				72	14	19	1	0	0
June 8–14	76	12	16	116	20	17	30	5	17
June 15–21	50	11	22	96	17	18	46	4	9
June 22–28	57	19	33	73	12	16	99	27	27
OPENING OF RIVER FISHERY									
June 29–July 5				5	1	20	86	17	20
July 6–12	172	38	22				109	24	22
July 13–19	44	9	20				6	1	17
July 20–26							2	0	0
July 27–Aug. 2									
Aug. 3–9									
Aug. 10–16									
Aug. 17–23									
Aug. 24–30									
Aug. 31–Sept. 6									
Sept. 7–13									
Total	399	89	22.3	400	71	17.8	379	78	20.6

APPENDIX TABLE 12.—*Fishery returns, by areas, from stream tagging*

Stream and year tagged	Returns from Yellowstone River area				Returns from Fishing Bridge area				Returns from Northern area			
	Number of first-year returns	Percent of total for year	Number of second-year returns	Percent of total for year	Number of first-year returns	Percent of total for year	Number of second-year returns	Percent of total for year	Number of first-year returns	Percent of total for year	Number of second-year returns	Percent of total for year
Arnica Creek:												
1950	2	4.5	0	0	4	9.1	1	7.7	10	22.7	2	15.4
1951	2	2.5	0	0	7	8.7	0	0	10	12.3	6	50.0
1952	0	0	0	0	2	5.7	0	0	8	22.8	1	50.0
1953	2	2.9	0	0	0	0	1	6.7	10	14.5	3	20.0
Total	6	2.7	0	0	13	5.7	2	4.8	38	16.5	12	28.6
Pelican Creek:												
1949	0	0	0	0	8	30.8	3	21.4	12	46.1	10	71.4
1950	3	5.6	0	0	20	37.0	1	11.1	31	57.4	5	55.6
1951	2	2.9	0	0	8	11.4	7	29.2	52	74.3	15	62.5
1952	3	3.5	0	0	23	27.1	0	0	55	64.7	12	92.3
1953	1	1.0	1	4.3	20	19.2	2	8.7	69	66.4	12	52.2
Total	9	2.7	1	1.2	79	23.3	13	15.7	219	64.6	54	65.1
Clear Creek:												
1953	0	0	0	0	5	11.6	0	0	27	62.8	6	54.5
Chipmunk and Grouse Creeks:												
1949	0	0	0	0	0	0	0	0	1	9.1	8	23.5
1950	1	5.9	0	0	0	0	0	0	4	23.5	4	33.3
1951	0	0	0	0	0	0	0	0	9	32.2	0	0
1952	0	0	1	20.0	0	0	0	0	6	50.0	1	20.0
1953	0	0	0	0	0	0	0	0	4	19.0	1	20.0
Total	1	1.1	1	1.4	0	0	0	0	24	27.0	14	19.7

APPENDIX TABLE 12.—*Fishery returns, by areas, from stream tagging*—Continued

Stream and year tagged	Returns from Southern area				Returns from West Thumb area				Total returns for year	
	Number of first-year returns	Percent of total for year	Number of second-year returns	Percent of total for year	Number of first-year returns	Percent of total for year	Number of second-year returns	Percent of total for year	Number of first-year returns	Number of second-year returns
Arnica Creek:										
1950	2	4.5	1	7.7	26	59.2	9	69.2	44	13
1951	0	0	2	16.7	62	76.5	4	33.3	81	12
1952	1	2.9	0	0	24	68.6	1	50.0	35	2
1953	5	7.1	1	6.7	52	75.4	10	66.7	69	15
Total	8	3.5	4	9.5	164	71.6	24	57.1	229	42
Pelican Creek:										
1949	2	7.7	0	0	4	15.4	1	7.2	26	14
1950	0	0	1	11.1	0	0	2	22.2	54	9
1951	3	4.3	0	0	5	7.1	2	8.3	70	24
1952	3	3.5	0	0	1	1.2	1	7.7	85	13
1953	7	6.7	3	13.1	7	6.7	5	21.7	104	23
Total	15	4.4	4	4.8	17	5.0	11	13.2	339	83
Clear Creek:										
1953	5	11.6	2	18.2	6	14.0	3	27.3	43	11
Chipmunk and Grouse Creeks:										
1949	3	27.3	6	17.7	7	63.6	20	58.8	11	34
1950	7	41.2	5	41.7	5	29.4	3	25.0	17	12
1951	13	46.4	11	73.3	6	21.4	4	26.7	28	15
1952	4	33.3	2	40.0	2	16.7	1	20.0	12	5
1953	13	62.0	3	60.0	4	19.0	1	20.0	21	5
Total	40	44.9	27	38.0	24	27.0	29	40.9	89	71